THE AMERICAN MINERALOGIST
JOURNAL OF THE MINERALOGICAL SOCIETY OF AMERICA

Vol. 18 SEPTEMBER, 1933 No. 9

CRYSTAL CAVITIES IN LAVAS FROM THE HAWAIIAN ISLANDS

KINGSLEY C. DUNHAM,* *Harvard University.*

CONTENTS

I. INTRODUCTION AND ACKNOWLEDGMENTS
II. MOILIILI QUARRY, HONOLULU
  Petrography of nephelite-melilite basalt
  Determination of minerals in veins and cavities
  Paragenesis
III. ALEXANDER DAM EXCAVATION, KAUAI
  Petrography of ankaratrite
  Determination of minerals in cavities
  Paragenesis
IV. LANAKAI HILLS, HAWAII
  Petrography of basalt
  Determination of minerals in amygdules
  Paragenesis
V. GENETIC FEATURES
  The Pegmatitoid stage
  The Hydrothermal stage
VI. OTHER MINERAL OCCURRENCES
VII. SUMMARY
VIII. BIBLIOGRAPHY

I. INTRODUCTION AND ACKNOWLEDGMENTS

The existence of veins containing good crystals of nephelite, augite and zeolites in a nephelite-melilite basalt exposed in a quarry near Honolulu has been known since 1900, when C. H. Hitchcock published his account of the geology of the island of Oahu. The same veins were mentioned by Whitman Cross (1915) but no detailed study of them was undertaken until 1930 when Professor Eakle upon his retirement to Honolulu made full collections of material from the crystal cavities not only of this locality but also of several others in the Hawaiian islands. At the time of his death in 1932, Professor Eakle was engaged in investigating these collections at the University of Hawaii, and it is to this work that he referred in a letter which has recently appeared in a memorial of his life written by C. Palache (1932). Professor Eakle had completed a number of chemical analyses, and had published a preliminary note on his work (1931).

---

* Commonwealth Fund Fellow, from the University of Durham.

The collections were acquired by Professor Palache for the Department of Mineralogy and Petrography of Harvard University, where at his suggestion the present author undertook to complete the study begun by Professor Eakle by determining the optical constants of both analyzed and unanalyzed minerals, and investigating the paragenesis and mode of origin of the minerals. Professor Eakle's notes were made available to the author and certain of his new analyses are included in the present account.

The author wishes to express his gratitude to Professor Palache for allowing him the opportunity of carrying this work to its conclusion, and also for helpful criticism and advice throughout the work. He also wishes to thank Professor E. S. Larsen, Jr. for discussing with him some of the optical determinations, and Dr. M. A. Peacock who was kind enough to make goniometric measurements on several crystals in order to confirm their identity. Unfortunately most of the crystals in the cavities did not prove amenable to goniometric treatment, either owing to corrosion or, in the case of the zeolites, because of the excessive development of vicinal faces. The author is also grateful to Professor L. C. Graton for allowing him to have polished surfaces of opaque minerals made by his special process.

Three principal localities are represented in the collection:

Moiliili quarry, referred to above. This lies within the city limits of Honolulu about one half mile east of the University of Hawaii grounds. The rock is quarried by the Honolulu Construction Company for use as road material.

The Alexander Dam which was being constructed for the McBryde Sugar Company on the island of Kauai.

The Lanakai hills, near Kailua, western Hawaii. Some of the specimens from this district are labelled "near railroad station, Kailua."

Several minor localities will also receive brief mention.

II. MOILIILI QUARRY, HONOLULU

Petrography of Nephelite-Melilite Basalt

The lava exposed in Moiliili quarry was first collected by C. H. Hitchcock and identified by G. P. Merrill (1900) as a nephelite-melilite basalt. Whitman Cross (1915) has described its petrography, and his account contains the following analysis and norm:

Analysis		Norm	
SiO_2	36.34	Leucite	8.28
Al_2O_3	10.14	Nephelite	21.02
Fe_2O_3	6.53	Anorthite	1.67
FeO	10.66	Diopside	17.39
MgO	10.68	Olivine	20.23
CaO	13.10	Akermanite	11.95
Na_2O	4.54	Magnetite	9.51
K_2O	1.78	Ilmenite	5.47
H_2O-	1.00	Apatite	2.35
H_2O+	1.00		
TiO_2	2.87		97.87
CO_2	0.15	H_2O	2.00
P_2O_5	1.02	Calcite	0.31
S	0.04		
MnO	0.20		100.18
	100.05		

In the hand specimen the rock is greyish brown in color and appears to be holocrystalline, without recognizable phenocrysts. The microscope reveals that the rock has a microporphyritic texture, with phenocrysts of olivine in a holocrystalline ground mass consisting of granular augite, nephelite, melilite and magnetite. The olivine phenocrysts show reaction rims of pyroxene, but apart from this the minerals are remarkably fresh, both distant from and near the cavities. The average size of the phenocrysts is about 0.75 mm., while the groundmass has an average grain of about 0.15 mm., the ragged augite crystals of the groundmass generally exceeding this figure. Apatite is present as an accessory mineral in the rock, in minor amounts only.

TABLE I. DETERMINATIVE CRITERIA FOR MOILIILI MINERALS

Name	Optical Character	ω α	β	ϵ γ	Crystal Form	Color, etc.
Nephelite	Uniaxial−	1.542		1.537	Hexagonal, prismatic Elongated parallel to "*c*"	Colorless, greasy lustre
Augite	Biaxial+ 2V near 60°	1.699	1.701	1.721	Flattened parallel to *b*(010) or *a*(100)	Dark green
Melilite	Uniaxial−	1.635		1.631	Tabular, much corroded	Yellowish-brown
Apatite	Uniaxial−	1.637		1.629	Acicular, hexagonal	Colorless
Magnetite	Opaque				Octahedra	Red coating. Strongly magnetic
Phillipsite	Biaxial− 2V mod.	1.493	1.497	1.500	Cruciform penetration twins	Colorless
Chabazite	Anomalous		1.485 (mean)		Rhombohedra, with penetration twins	Colorless to pale yellow
Hydronephelite		α^1 1.491		γ^1 1.499	Fibrous, radiating	White
Allophane	Isotropic		1.49 (mean)		Amorphous or cryptocrystalline crustification; banded	White
Calcite	Uniaxial−	1.670		1.485	Small "dogtooth" crystals, corroded. Crustifications	White, pink (rarely)

DETERMINATION OF MINERALS IN VEINS AND CAVITIES

Hitchcock (1900) described the veins traversing the basalt in the following words:

"The bluff is traversed by small veins full of nephelite, granular melilite and augite. Either of the minerals may form a layer of crystals, closely crowded together all standing vertically to the plane of occurrence. Veins three inches wide or less abound in these minerals, mixed with a multitude of acicular crystals of kaliophilite." The veins are irregular in form and probably represent shrinkage cracks or lines of cavities in the lava. They are now only partly filled, and it is evident from the open texture of the filling that the minerals have been free to grow in open spaces.

TABLE II. ANALYSES OF MOILIILI MINERALS

	I Nephelite	II Phillipsite	III Chabazite	IV Hydronepehlite
SiO_2	41.27	42.34	47.00	43.31
Al_2O_3	32.38	22.31	21.64	29.92
Fe_2O_3	1.08			
CaO	1.33	3.90	10.13	3.27
Na_2O	16.95	4.26		11.66
K_2O	4.65	6.78		
H_2O		19.70	20.98	12.38
	99.46	99.29	99.75	100.54

Analyst, A. S. Eakle

The accompanying table (Table I) summarizes the criteria used in determining the minerals. This data is here placed upon record so that even if the names here assigned to the minerals prove inapplicable when work such as M. H. Hey of the British Museum is carrying out on the zeolites is completed, the diagnostic criteria for the minerals will still be available. The new analyses of the Moiliili minerals made by Dr. Eakle are contained in Table II.

Several observations must be added to those in the tables. The determination of the magnetite was confirmed by examination of polished surfaces in reflected polarized light. The reddish coating was found to represent a hematitic marginal alteration product, the layer of which is very thin. The rest of the crystals consists wholly of magnetite, and no evidence of the presence of ilmenite was found.

The author is aware that the species hydronephelite is suspect, and that therefore the use of this name is open to objection. Nevertheless, the analysis (IV) shows that the material has a composition too far remote from natrolite to be described under this name, and since the mineral here occurs as a white alteration product of nephelite, just as did the original hydronephelite from Litchfield, Conn., and since it is chemically nearest to this material, it is proposed to retain the name here until this doubtful species has either been established or discredited. There is no indication in the optical properties of the material to suggest that it is not homogeneous, and if, therefore, it is a mixture of natrolite and diaspore as St. J. Thugutt (1932) has suggested, then these minerals must be in solid solution in one another. M. H. Hey (1932) states that he intends to thoroughly investigate this species in the near future; the examination of the Moiliili material was not therefore carried beyond the stage indicated by the data here recorded. Should the mineral prove to be a mixture, it is still possible that the term hydronephelite might usefully be retained for hydrous alteration products of nephelite of this type.

Allophane occurs as an amorphous or cryptocrystalline "metacolloidal" coating, exhibiting delicate banding on the microscopic scale. There was insufficient material in the Moiliili collection to make possible an analysis, but optically identical material from Alexander Dam has been analyzed. It should be noted that the refractive index indicates that the material is not amorphous silica, and the coatings have not the appearance of opaline silica.

A note must also be added concerning the analysis of phillipsite (II). Dr. Eakle's original analysis showed some 11.0% of Na_2O and no K_2O. Since it was evident from a morphological study that the mineral was phillipsite, it was decided to have the alkalis re-examined in order to check the correctness of this large divergence from the normal composition of phillipsite. The material used was some phillipsite remaining from Dr. Eakle's analysis; determination of alkalis in this by Mr. F. A. Gonyer showed Na_2O 4.26%, K_2O 6.78%. These figures have therefore been inserted in the analysis in the place of the original figures for alkalis.

PARAGENESIS

Study of the order of deposition of the minerals has revealed a surprisingly consistent succession of events in the filling of the veins and cavities. The sequence is summarized in Table III.

TABLE III. PARAGENESIS OF MINERALS, MOILIILI QUARRY AND ALEXANDER DAM

MOILIILI

	Phenocrysts	Groundmass	Pegmatitoid phase	Metacolloid phase	Zeolitic phase	
Olivine	———	Alteration to pyroxene				
Augite		———	—			Alteration to hydronephelite
Nephelite		———	—			
Melilite		———	—			
Apatite		———	———			
Magnetite		———	———			
Allophane				———		
Chabazite					———	
Phillipsite					———	
Hydronephelite						———
Calcite				—	———	—

ALEXANDER DAM

	Phenocrysts	Groundmass	Pegmatitoid phase	Metacolloid phase	Zeolitic phase	
Olivine	———	———	—			
Augite		———	—			
Nephelite		———	———			Alteration to hydronephelite
Magnetite		———				
Allophane				———		
Stilbite					——	
Gismondite					——	
Hydronephelite						———
Aragonite				-	———	—

Pegmatitoid phase. The term "*pegmatitoid*" is used to cover the segregations of pyrogene minerals which whenever they are present form the earliest fillings in the cavities. Though such segregations have long been recognized, they have had no proper name until A. Lacroix applied this term to them in 1928. It is interesting to note that the examples described by him are similar to those described here in that they occur in association with nepheline-bearing rocks. The term "pegmatitoid" is the equivalent of the term "segregation-vein" as used by the Mull authors (1924).

The term is an appropriate one because it suggests an analogy

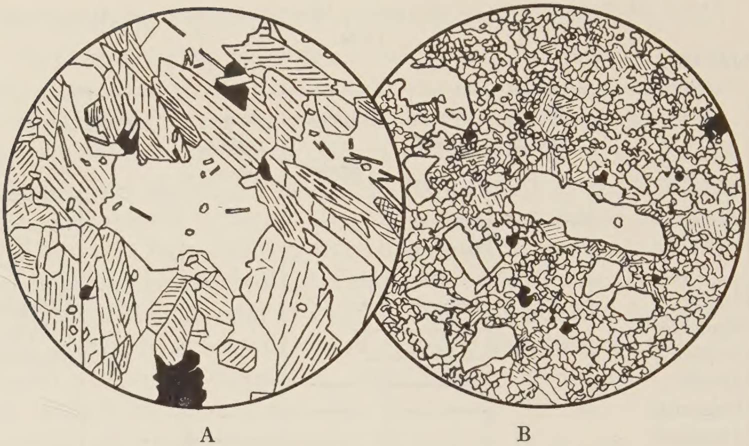


Fig. 1. Camera Lucida drawings illustrating the contrast in texture between the nephelite-melilite basalt of Moiliili quarry and its pegmatitoid phase.

A. Pegmatitoid phase. White areas, nephelite; augite crystals shaded to show cleavage; black areas, magnetite; needles are apatite.

B. The parent lava. Olivine phenocrysts (white) in groundmass of augite (showing cleavage), nephelite and melilite. Black areas are magnetite.

with the pegmatites associated with plutonic rocks. In the case of Moiliili the mineral composition of the pegmatitoid is qualitatively the same as that of the groundmass; there is, however, a great difference in grain size, as Table IV and the camera lucida drawings show.

Table IV. Contrast in Grain Size between Groundmass of the Parent Lava and the Pegmatitoid

	Greatest average dimensions of minerals in mm.	
	Groundmass	*Pegmatitoid*
Augite (ragged)	0.5	3.0
Nephelite	0.1	2.0
Melilite	0.15	2.0
Magnetite	0.1	1.0
Apatite	0.1	3.0

Quantitatively, there is a very significant difference between the mineral composition of the lava and the pegmatitoid; for while apatite is only rarely seen in the thin sections of the lava, it is very abundant in the coarse segregations. This difference will be further discussed in a later section.

Metacolloid phase. Following the deposition of the pyrogene minerals, a white coating of allophane was deposited on them. This is interesting mainly because it definitely preceded the crystallization of the zeolites. This white incrustation never covers the zeolitic minerals, whereas they are frequently seen to rest upon it. It is not, however, invariably present between the pegmatitoid and zeolitic phases.

Zeolitic phase. The zeolites, together with some carbonate material, constitute the last stage in the succession. No alteration of the pyrogene minerals is associated with the deposition of chabazite and phillipsite, but on the other hand, alteration amounting almost to complete pseudomorphous replacement of nephelite has occurred wherever hydronephelite is found.

III. ALEXANDER DAM EXCAVATION, KAUAI

Petrography of Ankaratrite

The rock in which the crystal cavities occur was collected from material excavated during the building of the Alexander Dam, on the island of Kauai. It is a melanocratic basaltic type, and is black in the hand specimen. The grain is fine. The texture is microporphyritic, with idiomorphic phenocrysts of olivine in a holocystalline groundmass composed of granular olivine, augite laths, magnetite, and nephelite, the amount of the last named constituent being very small. These characteristics show that the rock is an ankaratrite, a type apparently new to Hawaii, though the nearly-related limburgites have been abundantly found in the province (cf. Washington, 1923). N. E. A. Hinds (1925) has described several occurrences of nephelite basalt on Kauai, and the ankaratrite may be regarded as intermediate between the limburgite and nephelite basalt. No analysis is at present available.

Determination of Minerals in Cavities

The mineralogy of the cavity fillings in the ankaratrite has much in common with that of the Moiliili rock, and is summarized in Table V.

Crystals of augite are rare in these cavities, whereas olivine is comparatively abundant. Unfortunately the olivine is too much etched to be suitable for crystallographic study. No unaltered nephelite remains, though the hexagonal prismatic crystals are beautifully preserved as pseudomorphs in hydronephelite.

TABLE V. DETERMINATIVE CRITERIA FOR ALEXANDER DAM MINERALS

Name	Optical Character	ω α	β	ε γ	Crystal form	Color, etc.
Olivine	Biaxial+ 2V 90°	1.663	1.680	1.701	Deeply etched	Dark green
Augite	Biaxial+ 2V mod.		1.69 (mean)		Flattened parallel to *a*(100) which is the best developed face	Green; very intense absorption color
Nephelite	Pseudomorphs in hydronephelite				Hexagonal prismatic form	
Stilbite	Biaxial− 2V mod.	1.495	1.498	1.501	Typical twins, show hour-glass structure. *m*(110), *c*(001), and *b*(010)	Colorless
Gismondite	Biaxial−	1.538	1.543	1.548	Pseudotetragonal. Characteristic pyramidal form with rough faces	Colorless
Hydronephelite		α' 1.491		γ' 1.500	Fibrous	White
Allophane	Isotropic		1.49 (mean)		Amorphous incrustations	White
Aragonite	Biaxial−	1.683	1.680	1.537	Botryoidal masses	White

Allophane is more abundant than at Moiliili, and was present in sufficient amount to make possible an analysis (Table VI). In view of the frequency with which "amorphous silica" is described

TABLE VI. ANALYSIS OF ALLOPHANE, ALEXANDER DAM

SiO_2	30.2
Al_2O_3	40.3
MgO	1.8
H_2O	27.6
	99.9

Analyst, L. E. Davis, Honolulu

from cavities of the type here under discussion it is perhaps worth while at this point to call attention to the fact that such coatings may not always be silica, but may consist of hydrous silicate material as in the present instance. The magnesia in the analysis may be present as impurities, or as stevensite, which has much the same optical properties as allophane.

Paragenesis

The same stages as were recognized at Moiliili occur in the Alexander Dam cavities, and though there are some differences in mineralogy, an essentially similar sequence is plainly recognizable. Again there is a marked difference in texture between parent rock and pegmatitoid. The order of deposition is summarised in Table III.

IV. LANAKAI HILLS, HAWAII

Petrography of Basalt

The Lanakai lava is a brown amygdaloid of exceedingly fine grain and aphanitic aspect, without phenocrysts. The microscope shows that it is non-porphyritic and almost cryptocrystalline. The constituent minerals are labradorite in tiny laths, a monoclinic pyroxene and magnetite. The poecillitic texture is revealed only by the use of the highest power lens, but with this magnification it is evident that the rock contains no glass, but is holocrystalline. Neither quartz nor alkali feldspar were detected, and olivine is entirely absent. The rock is thus a normal basalt. Chloritic alteration extends throughout the whole rock, but is nowhere intense, and patches of what at first sight appear to be glass prove on close examination to consist of chlorite. The alteration shows no relation to the cavities.

Determination of Minerals in Amygdules

The amygdules are widespread through the rock, and have a rudely spherical shape, or may be elongated parallel to one another. The minerals include quartz, zeolites and a green fibrous material probably related to nontronite (Table VII).

Three of the zeolites represented had been analyzed by Dr. Eakle. Epistilbite, which had not been determined in this way, has been confirmed here by goniometric measurements made by Dr.

Peacock. The form proved to be identical within the limits of experimental error with that given for the mineral in Victor Goldschmit's "Atlas der Kristall Formen" and "Winkeltabellen."

TABLE VII. DETERMINATIVE CRITERIA FOR LANAKAI MINERALS

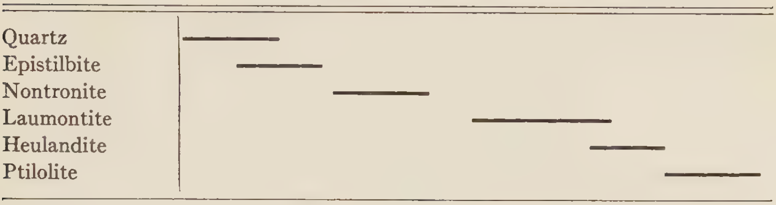
Name	Optical Character	ω α	β	ϵ γ	Crystal form	Color, etc. Max. size
Quartz	Uniaxial+	1.544		1.553	Characteristic. Sometimes doubly terminated	Colorless 2 mm.
Epistilbite	Biaxial− 2V small	1.505	1.515	1.519	Monoclinic twins with $m(110)$, $b(010)$ and $c(001)$	Colorless 3 mm.
Laumontite	Biaxial− 2V small	1.511	1.518	1.522	Elongated parallel to $m(110)$. $c(001)$ is poorly developed.	White 10 mm.
Heulandite	Biaxial+ 2V small	1.501	1.504	1.509	$b(010)$, $s(\bar{2}01)$, $t(201)$, $c(001)$. Rhombohedral	Colorless 9 mm.
Ptilolite		α' 1.475		γ' 1.478	Fibrous, woolly. Extinction parallel	White
Nontronite ?	Elongation +		1.56 (mean)		Fibrous	Greenish brown

TABLE VIII. ANALYSES OF MINERALS FROM THE LANAKAI HILLS

	I	II	III	IV	V
	Laumontite		Heulandite	Ptilolite	
	Lanakai Hills	Kailua		Lanakai	Kailua
SiO_2	52.34	52.30	57.28	65.56	65.66
Al_2O_3	22.27	23.38	17.76	10.55	10.77
CaO	10.83	10.36	7.18	5.46	5.43
Na_2O			2.95	3.07	3.90
H_2O	14.06	14.26	15.42	15.31	14.40
	99.50	100.30	100.59	99.95	100.18

Analyst, A. S. Eakle

TABLE IX. ORDER OF DEPOSITION OF LANAKAI MINERALS.



PARAGENESIS

Table IX summarizes the order of deposition of the minerals. Again there is a surprising constancy in this sequence, and while no single cavity shows the whole succession, no anomalies or reversals of the order were found, although a large number of amygdules were examined. The nontronite occupies a definitely intermediate position and occurs between quartz and epistilbite and the other zeolites. Cavities lined on their walls with nontronite do not contain quartz and epistilbite; cavities with nontronite as the central core contain in addition only these minerals. Many examples of both cases were observed, both in the hand specimen, and under the microscope. When ptilolite occurs, it is always the last mineral to crystallize, and there are many examples of amygdules lined with heulandite and having a woolly central filling of ptilolite. A few cavities showed beautiful examples of colorless heulandite crystals which had grown round radiating acicular laumontite crystals, the laumontite being clearly visible through the heulandite.

V. GENETIC FEATURES

The material from the principal localities having been described, it is now appropriate to consider the bearing of the observations made upon the more general problems of mineral genesis. The investigation has led to the recognition of two distinct groups of minerals in the veins and cavities; an anhydrous group, consisting of pyrogene minerals, similar in composition to the groundmass of the parent lava; and a later group of hydrous silicates.

THE PEGMATITOID STAGE

Stress has been laid upon the similarity in composition between the groundmass of the enclosing lava, and the coarse segregations of anhydrous silicates because this provides clear evidence of the source of the pyrogene minerals. The constituents of the pegmatitoids were undoubtedly derived from the rock in which they occur. Yet it is clear from their mode of occurrence that the minerals cannot have crystallized until the lava was more or less completely consolidated. Why then should a small residue of the magma have remained uncrystallized until after all the rest had solidified? Presumably this residue was subject to the same temperature-pressure conditions as the rest of the magma. A valuable clue is to be found in the concentration of apatite in the pegmatitoid phase at Moiliili. This indicates a richness in the mineralizers fluorine (the Moiliili apatite is a fluor-apatite) and phosphorus pentoxide. Further, the association of the pegmatitoids with zeolites suggests, as Lacroix (1928) has already pointed out, that the residue of the magma from which they were derived was unusually rich in water.

The analogy between the pegmatitoids and the pegmatites is thus complete. Both result from the crystallization of a volatile-rich rest-magma, and in both cases the grain is coarse because of the conditions induced by the presence of mineralizers. The panidiomorphic texture of the pegmatitoids here described is to be ascribed to their slow rate of crystallization, and to the freedom of the minerals to grow in open spaces. The cavities in which the pegmatitoids occur probably mark the loci of concentration of the residual liquors, perhaps in part in the gaseous state. When the form is more definitely vein-like, segregation into fissures resulting from contraction during the cooling of the lava may have taken place. There should exist some minimum depth below the lava-top, above which pegmatitoids cannot form because too great a freedom for escape of volatiles is possible; but unfortunately no field evidence is at present available to support this contention.

Some examples of pegmatitoids other than those here described may be mentioned before concluding this section. An occurrence almost identical with that at Moiliili is represented in a collection made by Professor Palache from the Capo di Bove, near Rome. Here vein-like cavities lined with nephelite, augite, melilite and apatite occur in an alkali-basaltic lava. The richness of the pegmatitoid in apatite is again a noteworthy feature. Segregation veins in olivine basalt on the island of Mull have been described by H. H. Thomas (1924). These contain an early phase composed of coarse augite and feldspar, followed by a later phase with analcite, chlorite, alkali feldspar and natrolite. Lacroix (1928) has described pegmatitoids from Wei t'chang, China; Bora-Bora, Polynesia; and Beaulieu and Rougiers, France. In all these cases, the rôle of water and mineralizers is apparent.

HYDROTHERMAL STAGE

It is suggested that the hydrous silicates are primary products also derived from the magmatic residuum responsible for the pegmatitoids. There are two alternatives to this hypothesis. One is the postulate that the zeolites are secondary products arising from the attack of circulating meteoric waters upon the lava. Since the constancy in the order of deposition of the zeolites cannot be explained upon this hypothesis, and since evidence of such attack is wanting, this mode of origin may be excluded. A second possibility is that the zeolites were introduced by hot solutions from some source outside the lava. There is no evidence, in the form of rock alteration, of the passage of such solutions. The zeolitic stage is therefore believed to result from crystallization from hot solutions which remained from the water-rich magma of the pegmatitoid stage. The phase of hydrous silicates is therefore designated the *hydrothermal* stage.

Some justification for the use of this term is provided by a study of the sequence of hydrous minerals. It was thought at first that the order of deposition of minerals in this phase might be explained on compositional grounds alone, and it was expected that the minerals would show a progressive increase in water-content. Table X shows that there is no such increase. In the Lanakai occurrences, there is a surprising constancy in the water-content; in the other two instances, the water-content actually decreases. While it is recognized that the water content of the zeolites is variable, it is scarcely possible to invoke this variation to account for the failure of the sequence to show increasingly hydrous minerals towards its end. Thus the view is put forward that the control of deposition in sequence was not composition but falling temperature. If this contention is correct, then clearly, hot solutions were involved and this stage is correctly described as hydrothermal.

A final observation must be added. It is an interesting fact in all three sequences that the last mineral to crystallize is a fibrous zeolite, and that fibrous zeolites do not occur earlier in the succession. Possibly the fibrous type crystallizes in preference to the well crystallized type at low temperatures.

Table X. Water Content of Minerals in the Hydrothermal Stage.

Figures in parentheses indicate average figures for the mineral concerned, there being no analysis available for the mineral from this locality

	Moiliili	$\%H_2O$	*Alexander Dam*	$\%H_2O$	*Lanakai Hills*	$\%H_2O$
Early	Allophane	(27)	Allophane	27	Epistilbite	(16)
	Chabazite	20	Stilbite	(17)	Nontronite	(20)
	Phillipsite	19	Gismondite	(25)	Laumontite	15
Late	Hydronephelite	12	Hydronephelite	(12)	Heulandite	14
					Ptilolite	15

VI. OTHER MINERAL OCCURRENCES

A number of less of important localities are represented in the collection made by Professor Eakle; brief descriptions of the minerals found follow here.

Salt Lake Crater. The county rock is an agglomerate. Thin sections show that it consists of lava fragments made up of olivine in a glass base, and shattered crystals of olivine and augite, the whole being cemented together by amorphous material. In cavities, typical laumontite is found, associated in many instances with green nontronitic material, which has preceded the laumontite in time of deposition. The similarity of this type of filling with that found in the Lanakai Hills suite is striking.

Dillinghams Quarry. Here spherical cavities occur in a dark basalt. The sole filling is aragonite, in well developed acicular crystals up to 10 mm. in length.

Halemaumau, Hawaii. The collection includes an explosion block hurled out of Halemaumau in 1924. The rock is grey in color, and contains many cavities. The grain is coarser than is usual with the Hawaiian lavas. Under the microscope, the rock is seen to have a moderately coarse ophitic texture, with labradorite laths and augite crystals. An opaque mineral is present in plates which in section have the same geometrical form as the labradorite. This mineral is evidently an original constituent of the rock. A polished surface showed that it is fairly strongly anisotropic; but the color has not the white quality of hematite; and the mineral is fairly strongly magnetic. It seems likely therefore that this mineral is hematite which is undergoing a transformation to magnetite.

The cavities in the rock contain small white crystals which have proved to be cristobalite, with refractive index 1.485.

VII. SUMMARY

1. The mineralogy of veins, cavity fillings and amygdules in lavas from three localities in the Hawaiian islands is recorded, to-

gether with new analyses of certain of the minerals made by the late Professor A. S. Eakle, who was the collector of the material.

2. In two of these cases, segregations of pyrogene minerals qualitatively similar in mineral composition to the groundmass of their parent lavas were found. These are described as *pegmatitoids*, using the term proposed by Lacroix. It is shown that the late crystallization of these and their coarseness in grain are to be ascribed to crystallization from volatile-rich magmatic residua.

3. In each case a white coating of a hydrous aluminium silicate followed the deposition of the pegmatitoid, but preceded the crystallization of a series of zeolites.

4. An orderly succession of zeolites is described from all three localities. It is suggested that these are primary minerals representing the hydrothermal stage of the lava-magma.

5. Thus just as in the depths of the earth, the magma at the surface upon crystallization tends to produce a "rest-magma," rich in water and volatile components. From this, coarse-grained anhydrous minerals crystallize first, and hydrous silicates follow at a later and therefore cooler stage.

6. A number of less important mineral localities in the islands are also described.

VIII. BIBLIOGRAPHY

Bailey, E. B., Thomas H. H. et aliter, 1924. The Tertiary and Post-Tertiary Geology of Mull, Loch Aline and Oban: *Mem. Geol. Surv. Scotland*, p. 138.

Cross, Whitman, 1915. The Lavas of Hawaii and their Relations: *Prof. Paper* **88**, *U.S.G.S.* p. 21.

Eakle, A. S., 1931. The minerals of Oahu: *Mid-Pacific Magazine*, October, pp. 341–343.

Hey, M. H., 1932. Studies of the Zeolies. Part III, Natrolite and Melanatrolite *Mineral. Mag.*, **xxiii**, p. 244.

Hinds, N. E. A., 1925. Melilite and Nephelite Basalt in Hawaii: *Jour. Geol.*, **xxxiii**, pp. 526–539.

Hitchcock, C. H., 1900. The Geology of Oahu: *Bull. Geol. Soc. Amer.*, **xi**, p. 47.

Lacroix, A., 1928. Les Pegmatitoides des Roches Volcaniques a facies basaltique: *C. R. Acad. Sci.*, Paris, pp. 321–326.

Merrill, G. P., 1900. Nepheline Melilite Basalt from Oahu, Hawaiian Islands: *Amer. Geologist*, **xxv**, pp. 312–13.

Palache, C., 1932. Memorial of A. S. Eakle: *Bull. Geol. Soc. Amer.*, **xliii**, pp. 46–52.

Thugutt, St. J., 1932. Sur l'epinatrolite, mineral composant l'hydronephelinite: *Archive de mineralogie de la societe des sciences et des lettres de Varsovie*, **vii**, pp. 143–144.

Washington, H. S., 1923. Petrology of the Hawaiian Islands; III. Kilauea and General Petrology of Hawaii: *Amer. Jour. Sci.*, 5th ser., **vi**, pp. 338–367.

IMMERSION LIQUIDS OF INTERMEDIATE REFRACTION (1.450–1.630)

ROBERT D. BUTLER, *Massachusetts Institute of Technology, Cambridge, Mass.*

ABSTRACT

A most convenient set of liquid standards for use in ordinary immersion technique has optical properties linearly related to index. This requires an optically ideal solution system. The series described here covers the intermediate index range (1.450–1.630) and has for end members α-monochlornaphthalene and a high boiling kerosene fraction. The resulting solutions have index related to composition by practically a straight line, and temperature coefficients and dispersions are linear functions of index, hence the liquids constitute an optically ideal solution series. After eighteen months of laboratory use, the properties remain unchanged; the liquids are therefore excellent for ordinary immersion technique, and it is suggested that they might find use in the double variation method. Directions are given for the exact duplication of the series of liquids.

INTRODUCTION

Lists of liquid standards for use in the determination of indices of crystals by the immersion method have been given by van der Kalk,[1] De Lorenzo and Riva,[2] Wright,[3] Merwin and Larsen,[4] Merwin,[5] Johannsen,[6] Larsen,[7] Borgström,[8] Emmons,[9,10,11] Chamot and

---

[1] Schroeder van der Kalk, Tabellen zur mikroskopischen Bestimmung der Mineralien nach ihrem Brechungsindex; 2 Aufl., *Wiesbaden*, **1906.**

[2] De Lorenzo and Riva, Die Krater von Vivara auf den Phlegreischen Inseln: *Mem. Roy. Acc. Sci. Napoli*, **X,** 1901, pp. 1–60.

[3] Fred Eugene Wright, The methods of petrographic-microscope research: *Carnegie Publication*, No. **158,** Washington, 1911, pp. 97–98.

[4] H. E. Merwin and E. S. Larsen, Mixtures of amorphous sulphur and selenium as immersion media for the determination of high refractive indices with the microscope: *Amer. Jour. Sci.*, **XXXIV,** 1912, pp. 42–47.

[5] H. E. Merwin, Media of high refraction for refractive index determinations with the microscope; also a set of permanent standard media of lower refraction: *Jour. Washington Acad. Sci.*, **III,** 1913, pp. 35–40.

[6] Albert Johannsen, Manual of petrographic methods, *New York*, **1918,** pp. 249–265.

[7] Esper S. Larsen, The microscopic determination of the nonopaque minerals: *U. S. Geol. Survey*, *Bull.* **679,** 1921, pp. 14–20.

[8] L. H. Borgström, Ein Beitrag zur Entwicklung der Immersionmethode: *Comm. Géol. de Finlande, Bull.* No. **87,** 2, 1929, pp. 58–63.

[9] R. C. Emmons, The double dispersion method of mineral determination (preliminary paper); *Am. Mineral.*, **13,** 1928, pp. 504–515.

[10] R. C. Emmons, The double variation method of refractive index determination (second paper): *Am. Mineral.*, **14,** 1929, pp. 414–426.

[11] R. C. Emmons, A set of thirty immersion media; *Am. Mineral.*, **14,** 1929, pp. 482–483.

Mason,[12] Winchell,[13] and Harrington and Buerger.[14] Earlier workers paid scant attention to properties other than index, but following the introduction of the Emmons variation methods,[15] the properties of temperature coefficient and dispersion have become of prime importance. Properties are listed rather completely for low index media by Harrington and Buerger,[16] for liquids of intermediate refraction by Emmons,[17] and for high index media by Borgström.[18]

Unfortunately, the liquids of the intermediate range listed by Emmons form a disconnected series, and consequently the properties of any one member may be *discontinuous* with respect to those of the adjacent members. The conveniences afforded by a series with optical properties *continuously* variable with refractive index have been stressed by Buerger in a preceding paper, [19]in which he suggests the use of optically ideal solutions which have properties linearly related to composition.

The common difficulty encountered with standards of liquid solutions is the comparatively rapid change in index with use due to differential evaporation of the end members. Johannsen prepared a set[20] which changed 0.003 in two years. Wright's standards[21] changed 0.002 in one year. It is not stated in which index region these maximum changes occurred, but a change of 0.004 in the quartz-feldspar index region was observed on an intermediate series (crude kerosene-halowax mixtures) used in this laboratory for three years. In the present paper, an optically ideal solution series is described in which the desired constancy has been attained.

DESIRED FEATURES OF AN IMMERSION SERIES

A complete set of immersion media consists of several series. For convenience, the components of the set used in this laboratory are listed in Table I. Properties must be continuously variable with index within any given series, and should present as much continuity as possible from series to series. Both these requirements can be easily satisfied in the lower and intermediate ranges.

---

[12] E. M. Chamot and C. W. Mason, Handbook of chemical microscopy, Vol. 1, *New York*, **1930**, pp. 378, 385.

[13] A. N. Winchell, The microscopic characters of artificial inorganic solid substances or artificial minerals, *New York*, **1931**, pp. 61–70.

[14] V. F. Harrington and M. J. Buerger, Immersion liquids of low refraction: *Am. Mineral.* **16**, 1931, pp. 45–54.

[15] R. C. Emmons, Reference 9, pp. 504–515; Reference 10, pp. 414–426.

[16] V. F. Harrington and M. J. Buerger, *loc. cit.*, pp. 50–54.

[17] R. C. Emmons, Reference 11, p. 483.

[18] L. H. Borgström, *loc. cit.*, pp. 59–62.

[19] M. J. Buerger, The optical properties of ideal solution immersion liquids: *Am. Mineral.*, **18**, 1933, pp. 325–334.

[20] Albert Johannsen, *loc. cit.*, p. 262.

[21] Fred. Eugene Wright, *loc. cit.*, p. 97.

Considering a single series, the following features[22] are desirable:

1. Adjacent liquids should have closely identical optical properties other than index. Therefore, all the properties should be continuously related to composition and the increment other than index from member to member should be a minimum. This has been thoroughly discussed by Buerger.[23]

2. Any two liquids should be miscible, and the index of any intermediate member should be a straight line function of its composition. This feature allows one instantly and certainly to make up a liquid of any desired index from the available standards. The making of the original standards from the end members is similarly simplified.

3. The liquids should be permanent, which implies constancy of properties under all laboratory conditions.

TABLE I. TABULATED RANGES AND COMPONENTS OF AN IMMERSION SET.

	Range	Components
Solid-solid series	>1.850	Sulphur—Selenium melts and Piperine—Arsenic iodide—Antimony iodide melts
Solid-liquid series	1.850–1.785 1.780–1.740	Metallic iodides—Methylene iodide Sulphur—Methylene iodide
Liquid-liquid series	1.735–1.635 1.630–1.455 1.450–1.350	Methylene iodide—α-monochlornaphthalene α-monochlornaphthalene—Kerosene fraction Kerosene distillates*

* Do not form a simple series according to the terminology adopted in this paper.

4. The extreme members of any series should have closely connecting properties to the adjacent member of the next series.

5. Solid matter should not separate out on standing.

6. They should be clear and colorless.

7. They should be free from objectionable odors.

---

[22] Esper S. Larsen, *loc. cit.*, p. 14.

[23] M. J. Buerger, *loc. cit.*

8. They should, preferably, be non-poisonous and harmless.
9. They should not dissolve inorganic material.

Any series should cover the maximum possible index range so that the variables in the complete set are at a minimum. Obviously, if three end members resulting in two series are utilized to cover a range which could well be covered by two end members and one series, an additional complication is introduced into the completed system.

SELECTION OF END MEMBERS

GENERAL CONSIDERATIONS. The first two requisites of the preceding section call for a series of liquids made up by mixing two miscible pure end members. Obviously, physico-chemical similarity between end members is desired. The third requirement stipulates that the liquids must have low vapor pressures at experimental temperatures, and that the vapor pressures of the end members be approximately equal, resulting in stability through minimum and equal evaporation of the end members. (This cannot be satisfied by the methylene iodide liquids, or liquids containing dissolved or suspended solid material.)

THE LOWER END MEMBER. Harrington and Buerger demonstrated that high boiling kerosene fractions have constant index values[24] with respect to evaporation, behaving essentially as pure liquids. As their distillates composed the individuals of the lower range, one of their higher members should constitute a favorable lower end member of the intermediate series.

Because of the nature of these hydrocarbons, any high boiling kerosene fraction is not a pure liquid but its optical properties are analogous to those possessed by a pure liquid.[25] The 220°–225°C fraction obtained by Harrington and Buerger[26] meets the requirements with a vapor pressure comparable to that of α-monochlornaphthalene (see beyond), a low index, and, as an end member, presents properties linking with those of the lower range.

Distillation of 3.5 gallons of kerosene was accomplished on a simple fractionating column without reflux control. 300°F flashpoint kerosene is a higher grade raw material than crude kerosene and should be used. It is a cheap commercial product.

At temperatures greater than 200°C, fractions were isolated every 3° or 5°C depending on the volume of the fraction. The combination of cuts covering the 228°–240°C range was found to present the optimum qualities of index and volume. This combination of 1200 cc. volume was redistilled and sharper cuts taken. The fractions boiling off between 220° and 236° were combined and set aside as the lower end member which was a clear and virtually colorless liquid, possesses a faint paraffin odor and has an index value, $n_D = 1.4500 \pm 0.0001$ at 22°C.

---

[24] V. F. Harrington and M. J. Buerger, *loc. cit.*, pp. 50–51.

[25] V. F. Harrington and M. J. Buerger, *loc. cit.*, p. 46, footnote.

[26] V. F. Harrington and M. J. Buerger, *loc. cit.*, p. 50.

It is to be noted here that fractionating apparatus in general is quite individual, and in work with this type of liquid, where the separate cuts have distinct differences in refractive indices, the index of a cut is a better criterion than the temperature in considering the efficiency of the distillation. Hence, the index of each fraction should be tabulated to facilitate the combination of the optimum fractions as the end member.

THE UPPER END MEMBER. Mixtures of petroleum compounds and α-monochlornaphthalene were known to be workable refractive standards.[27] Alpha-monochlornaphthalene was chosen as the upper end member partly because it was known to be completely miscible with kerosene, and partly because it gave a favorable combination of high index with high stability and freedom from color[28] and objectionable odor. Its boiling point is 260°C, and the particular stock utilized in this investigation has an index, $n_D = 1.6324 \pm 0.0001$ at 22°C. Alpha-monochlornaphthalene is a commercial product and may be purchased at a reasonable cost from the Eastman Kodak Company of Rochester, New York.

MIXING THE END MEMBERS

The theory of liquid mixtures has been discussed by Buerger[29] with especial reference to the present case. It is convenient to know beforehand how the composition is related to the index, hence by mixing about five known proportions of the end members, shaking well, and determining their various indices, it is possible to predetermine this relation. The form of this relation is then plotted on graph paper, as in Fig. 1, with the dashed line at the center representing the straight line which would correspond to the mixing curve if the system were absolutely ideal. However, the deviation of the curve from the theoretical straight line is very slight, and its only effect on the properties of the series is on the composition—index values. The upward arching probably indicates a slight increase in the additive density immediately following the mixing.

---

[27] R. D. Reed, Heavy mineral investigations of sediments: *Econ. Geol.*, **XIX**, 1924, p. 332.

[28] Halowax is an impure variety of α-monochlornaphthalene and separates gummy material which precipitates on the containers.

[29] M. J. Buerger, *loc. cit.*

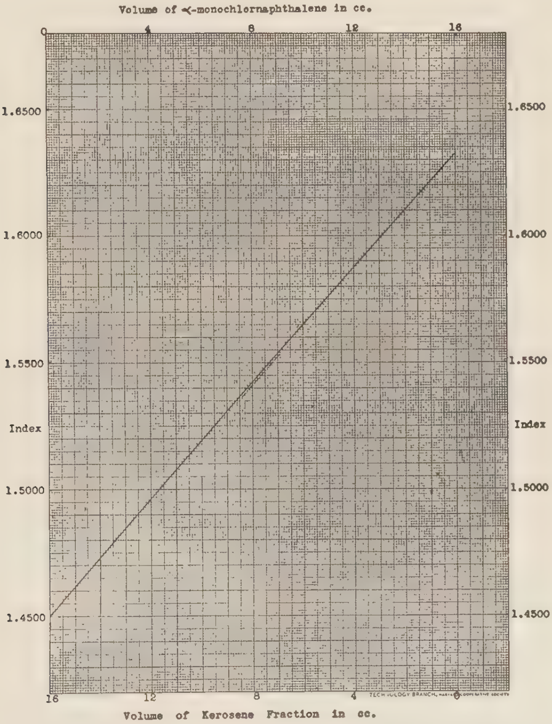


FIG. 1. Mixing curve which indicates the form of the composition—index relation for the series. The dashed line denotes the position of a straight line connecting the index values of the end members.

As the composition-index relation approaches a linear function and ideal conditions, the system may be termed near-ideal, and if other properties are linearly related to index, the system will be designated, optically ideal.

The actual working graph of Fig. 1 was plotted to a large scale, and the volumes of the end members to form any given index have been read directly. These volumes are listed in Table II.

TABLE II.

Composition in cc.		Index, n_D, at various Temperatures				Weighted and Corrected† dn/dT	Index, 22°C, at various Wavelengths					Dispersion‡ at 22°C
Kerosene fraction	α-mono-chlornaphthalene	10°C	22°C	36°C	50°C		Hydrogen n_F 4861A	Thallium 5351A	Sodium n_D 5893A	Hydrogen n_c 6563A	Lithium 6708A	
16.00	0.00		1.4500*			.000402	1.4567		1.4505	1.4480		.0087
15.58	0.42	1.4598	1.4550	1.4498		.000403	1.4626	1.4583	1.4553	1.4530	1.4523	.0093
15.13	0.87	1.4647	1.4601			.000404						.0099
14.70	1.30	1.4697	1.4650		1.4538	.000406						.0105
14.28	1.72	1.4747	1.4700		1.4590	.000407						.0111
13.86	2.14	1.4798	1.4750	1.4693	1.4635	.000408	1.4837	1.4792	1.4753	1.4720	1.4715	.0117
13.32	2.58	1.4849	1.4801		1.4692	.000409						.0123
12.99	3.01	1.4900	1.4852		1.4738	.000411						.0129
12.55	3.45	1.4949	1.4900		1.4786	.000412						.0135
12.11	3.89	1.4999	1.4950		1.4835	.000413						.0141
11.69	4.31	1.5047	1.5000	1.4940	1.4885	.000414	1.5106	1.5049	1.5001	1.4959	1.4955	.0147
11.26	4.74	1.5097	1.5050		1.4931	.000415						.0153
10.82	5.18	1.5145	1.5100		1.4980	.000417						.0159
10.38	5.62	1.5199	1.5150		1.5040	.000418						.0165
9.95	6.05	1.5245	1.5201		1.5083	.000419						.0171
9.51	6.49	1.5295	1.5250	1.5191	1.5131	.000420	1.5381	1.5313	1.5255	1.5203	1.5188	.0177
9.07	6.93	1.5345	1.5302		1.5181	.000421						.0183
8.63	7.37	1.5399	1.5350		1.5230	.000422						.0189
8.19	7.81	1.5446	1.5401		1.5282	.000424						.0195
7.75	8.25	1.5498	1.5451		1.5331	.000425						.0201
7.32	8.68	1.5549	1.5500	1.5440	1.5380	.000426	1.5653	1.5566	1.5500	1.5446	1.5434	.0207
6.89	9.11	1.5597	1.5550		1.5430	.000427						.0213
6.46	9.54	1.5649	1.5600		1.5481	.000428						.0219
6.02	9.98	1.5699	1.5649		1.5530	.000430						.0225
5.58	10.42	1.5747	1.5700		1.5581	.000431						.0231
5.14	10.86	1.5797	1.5752	1.5690	1.5632	.000432	1.5924	1.5826	1.5751	1.5687	1.5676	.0237
4.70	11.30		1.5800		1.5684	.000433						.0243
4.25	11.75		1.5851		1.5728	.000435						.0249
3.80	12.20		1.5900		1.5781	.000436						.0255
3.35	12.65		1.5950		1.5830	.000437						.0261
2.90	13.10	1.6048	1.6000	1.5934	1.5877	.000438	1.6196	1.6086	1.6000	1.5929	1.5914	.0267
2.45	13.55		1.6049		1.5928	.000439						.0273
2.00	14.00		1.6102		1.5975	.000441						.0279
1.55	14.45		1.6150		1.6025	.000442						.0285
1.10	14.90		1.6200		1.6076	.000443						.0291
0.65	15.35	1.6297	1.6251	1.6185	1.6126	.000444						.0297
0.20	15.80		1.6301	1.6239	1.6171	.000445	1.6521	1.6398	1.6300	1.6218	1.6206	.0303
0.00	16.00		1.6324			.000446	1.6549		1.6326	1.6241		.0306

* Indices of the end members are correct to one in the fourth decimal place. Kerosene fraction = 1.4500 ± 0.0001; α-monochlornaphthalene = 1.6324 ± 0.0001

† Temperature coefficients computed from the formula locating the straight line in Fig. 4.

‡ Dispersions read from the straight line in Fig. 5.

Description of Properties

General Description. Following Buerger's reasoning,[30] the resulting system of mixtures should constitute optically ideal solutions if the end members were wisely chosen. The index should be a straight or near-straight line function of composition, and similarly, the other important properties should be linearly related to composition and therefore to index.

Determinative Methods. The optical properties of liquid standards are readily determined through index measurements subject to controlled variation of conditions. Thus, temperature coefficients are found by taking index readings at several temperatures and finding the change in index per degree temperature change, keeping the utilized wavelength constant; similarly, dispersions are found by index readings at a constant temperature and various wavelengths.

All measurements were accomplished under rigorous control of conditions. Indices for standardization and temperature coefficients were measured on a Spencer Abbé refractometer with two thermometers and three constant pressure reservoirs to insure accurate values of temperature. Indices were determined by the hollow prism, minimum deviation method, with a single circle goniometer, from a hydrogen source and lithium, sodium, and thallium flames. Temperature control of the liquid in the hollow prism can be maintained by circulating thermally controlled water through a hollow chamber which forms the base of the prism. Such a prism was designed by Professor Buerger, and experience has shown it to work satisfactorily. Fig. 2 is an explanatory diagram of the device.

Index. The indices of the end members were determined to fourth decimal place accuracy previous to plotting the mixing curve. The most convenient index of the members, n_D at 22°C, was measured following the mixing. Because of the lack of sensitivity of buret readings, the addition of a few drops of one of the end members was necessary in some cases to bring the liquid to the correct volume and consequently the desired index. The indices of the complete set at 22°C were remeasured two weeks after mixing to detect any possible changes. However, there were none beyond the limits of instrumental accuracy.

---

[30] M. J. Buerger, *loc. cit.*

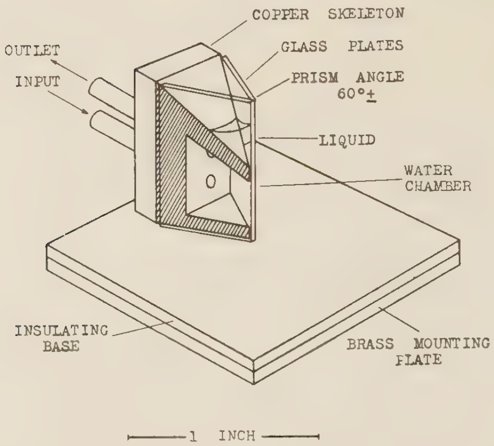


Fig. 2. Sketch of temperature-controlled hollow prism used in the minimum deviation method for index determinations. The glass plates are united to the copper element by Bakelite varnish.

Additional index values were measured at 10°, 36°, and 50°C. Indices are listed in Table II. The readings at 10° may be regarded as dubious as they were made in the summer, and fogging of the prisms (the dew-point phenomenon) caused imperfect resolution. The index of each member plotted against temperature is shown by the system of lines on the left-hand side of Fig. 3. Bearing in mind the unreliability of the 10°C readings, it can be seen that for any individual liquid the available data warrant a linear temperature-index relationship.

Temperature Coefficient. The temperature coefficient, dn/dT, corresponding with the slopes of the straight lines in Fig. 3, is the rate of change of index with temperature. This property is utilized in the Emmons Variation Method[31] and must be accurately determined with a view to possible application.

The readings at 22°C and 50°C present the best experimental values with a maximum spread which covers most of the practical range of temperature variations. Therefore, temperature coefficients calculated over this range represent the best data. The temperature coefficients for this spread are shown plotted against index in Fig. 4. The scale of the temperature coefficients is greatly exaggerated; if it is plotted to the same scale as the index, the

[31] R. C. Emmons, Reference 10, pp. 418–420.

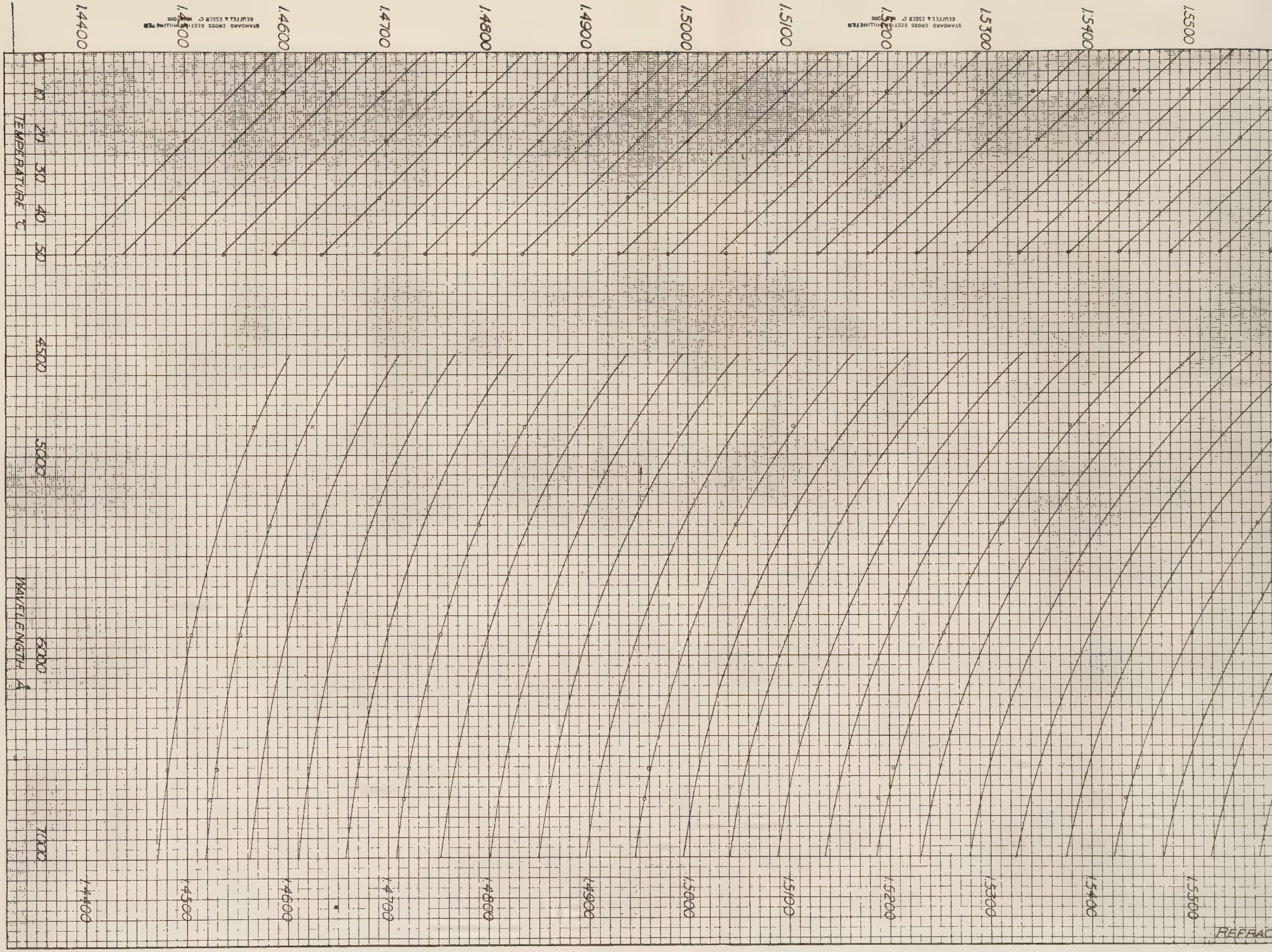
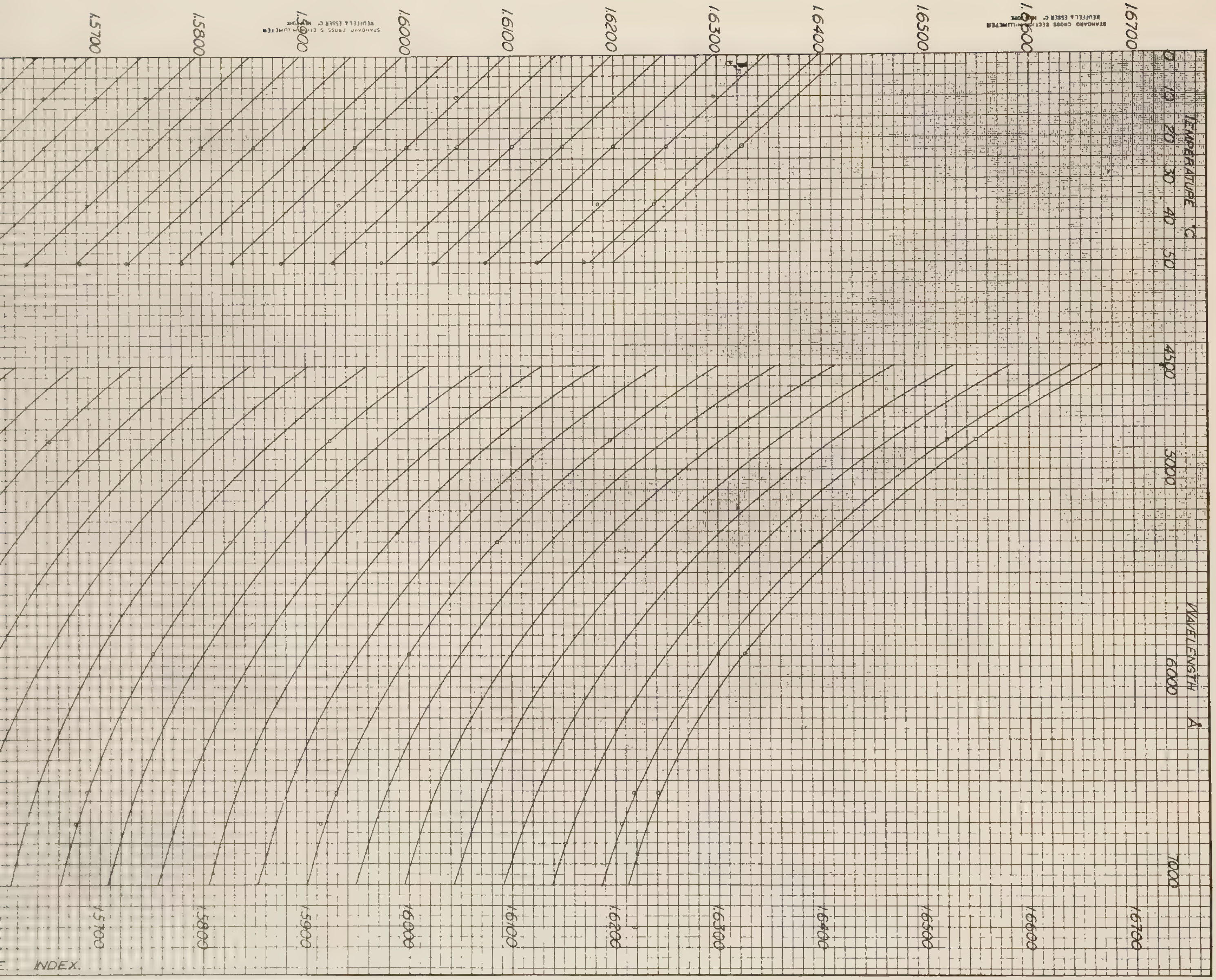


FIG. 3. Properties of the immersion series. The index of the members is plotted against temperature in the left-hand system of lines and ag



st wavelength in the right-hand system of dispersion curves. Deviations from experimental points are explained in the text.

experimental points fall on a straight line, and the slope of the line is near zero.

The best straight line to represent the collection of experimental points was determined by the method of averages,[32] and its equation found to be: $dn/dT = 0.0024332\,n + 0.0000491$.

The weighted and corrected temperature coefficients of the individual liquids have been calculated from this formula and listed in Table II. As these represent the best obtainable values, they have been used to determine the slopes of the temperature-index relations of Fig. 3, using the 22°C readings, whose certainties were most assured, to fix the positions of the lines. Any deviations of these lines from the experimental points is attributed to difficulties in temperature regulation.

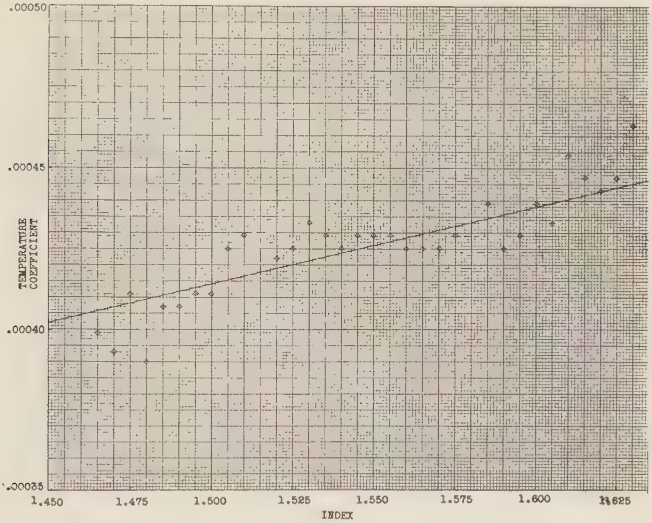


FIG. 4. Temperature coefficient, dn/dT, plotted against index, n_D, with the scale of the ordinate highly exaggerated. The best straight line representing the experimental points is given by: $dn/dT = 0.0024332\,n + 0.0000491$.

DISPERSION. The arbitrary dispersion in common use, $n_F - n_C$, is the difference in index exhibited by a liquid between the F and C wavelengths of hydrogen. The variation methods utilize[33] dispersion in the general sense, i.e., the change of index with wavelength.

The indices of liquids spaced at n_D intervals of 0.025 (every fifth member of the series) were measured directly in the *F* and *C* wavelengths of hydrogen and in lithium, sodium, and thallium wavelengths. Results are tabulated in Table II. From these data, $n_F - n_C$ has been computed, and is shown plotted against index in Fig. 5. The experimental values fell on a straight line whose equation is: $(n_F - n_C) = 0.1200\ n - 0.1653$. Dispersion values for each individual of the series have been read from the graph and listed in Table II. Those for every fifth liquid coincide for the most part with the experimental values as these are exceptionally good.

---

[32] Joseph Lipka, Mechanical and graphical computation, *New York*, **1918**, p. 126.

[33] R. C. Emmons, Reference 9, pp. 505–512; Reference 10, p. 417.

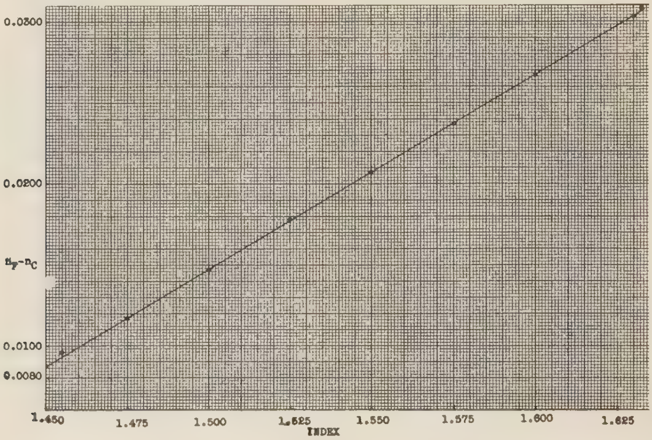


FIG. 5. Dispersion, $(n_F - n_C)$, plotted against index, n_D. The straight line connecting the points is given by: $(n_F - n_C) = 0.1200\ n - 0.1653$.

The aforementioned prediction by Buerger that the dispersion of an ideal solution series will be linearly related to index is therefore fulfilled, and the liquids form an optically ideal system.

The dispersion curves of the individual liquids have been established so values might be read directly when using the variation method. This was accomplished as directed by Buerger[34] through the plotting of carefully determined wavelength-index values of a single liquid on Hartmann dispersion formula graph paper, reading off interpolated and extrapolated relationships, and drawing a progressive wavelength scale on a separate graph. Fig. 6 shows the system of straight line dispersion relationships for liquids spaced at n_D intervals of 0.025 as a result of plotting their values on this graph paper.

---

[34] M. J. Buerger, *loc. cit.*

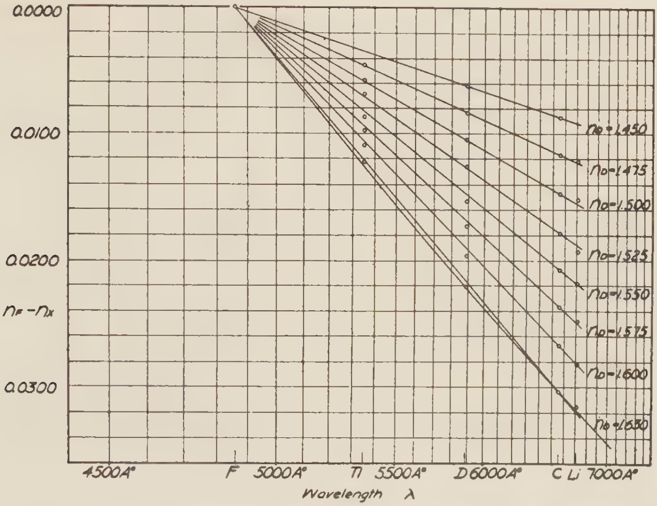


FIG. 6. Dispersions of liquids spaced at n_D intervals of 0.025, plotted on Hartmann dispersion formula graph paper. The lowest line represents the experimental points better than the corresponding straight line and is used in determining the wavelength scale of Fig. 7.

The above wavelength scale calibration is effected by reading values, not from one of the straight lines, but from a flat curve similar to the bottom line in Fig. 6, which represents the data somewhat better than the corresponding straight line. This gives index differences, $n_F - n_x$, which may be changed to absolute index, or which may give absolute index values directly, depending on the ordinate scale chosen. This holds for any wavelength or wavelength difference.

From the flat curve, differences in index of the liquid for differences of wavelength from the sodium wavelength ($n_x - n_D$) were read. These were plotted vertically against the horizontal line, $n_D n_D$, of Fig. 7, resulting in the wavelength scale for this particular liquid. The upper straight line of Fig. 6 (the lowest liquid) was treated identically, and from the combination of points, straight lines were drawn which intersected at the 'projection point.' These lines are lines of equal wavelength. The height of a line, at any point, drawn to the 'projection point' from a designated value on the wavelength scale will represent the difference in index ($n_x - n_D$) between this wavelength and the sodium wavelength at 22°C at that point. Buerger has stated that in optically ideal solu-

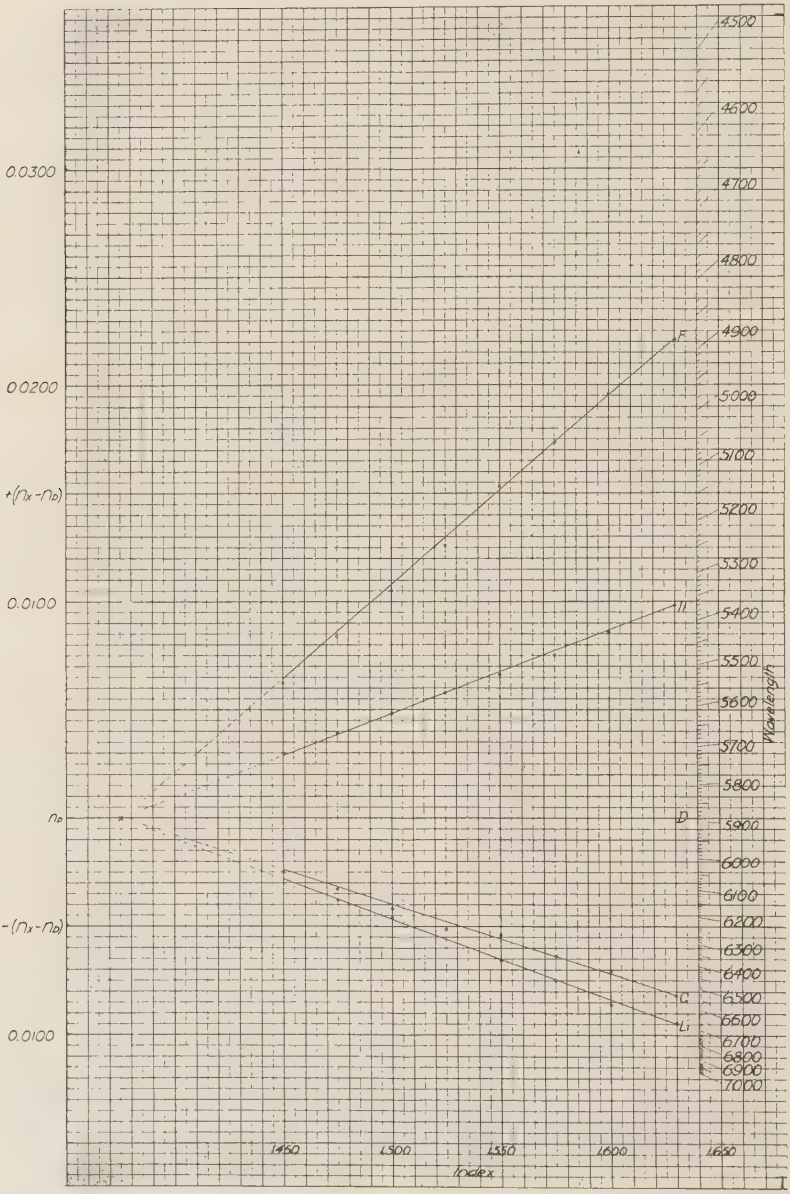


FIG. 7. Dispersion relations. Given a liquid whose index is known at 22°C for the sodium wavelength, to obtain its index at any other wavelength (i.e. given n_D, to find n_x): locate the desired wavelength on the righthand vertical scale; draw a straight line from this point to the projection point; the vertical distance between this straight line and the base line at the given n_D value is the index correction to be algebraically added to n_D to get the desired index, n_x.

tion systems, such a proportionality relation between wavelength and index will necessarily have to hold true.

With this wavelength scale established, the accurate drawing of the individual dispersion curves on ordinary coordinate paper (as in Fig. 3) is simplified as an infinite number of points are available for any liquid of index n_D. Considering a single liquid, the index value in sodium light fixed, differences in indices for other wavelengths ($n_x - n_D$) are read from Fig. 7, adjusted to absolute index n_x, and plotted against the wavelength. The system of dispersion curves on the right side of Fig. 3 shows the form of the index-wavelength relationship for the complete series.

CONSTANCY. The constancy of the properties of a series of immersion media depend on stability with respect to original composition. As the index is a direct function of composition, changes in index will denote inconstancy.

The primary fault of mixtures of liquids is the difference in vapor pressures of the components, hence, differential evaporation is to be expected with a resulting change in properties. Of these changes, index alone is serious; dispersion is a difference in index and would not change notably, and the change in the temperature coefficients would be in the fifth or sixth decimal places.

The end members and certain mixtures underwent evaporation

TABLE III. EVAPORATION RESULTS.

Liquid	Original Index	Index after 20 hours of evaporation	Change in Index
Crude kerosene	1.4483	1.4517	0.0034
300° F Flashpoint Kerosene	1.4558	1.4562	0.0004
Kerosene fraction end member	1.4500	1.4499	−0.0001
75% Kerosene fraction, 25% α-monochlornaphthalene	1.4997	1.5014	0.0017
50% Kerosene fraction, 50% α-monochlornaphthalene	1.5498	1.5531	0.0033
25% Kerosene fraction, 75% α-monochlornaphthalene	1.5872	1.5910	0.0038
α-monochlornaphthalene end member	1.6324	1.6323	−0.0001
Halowax	1.6345	1.6344	−0.0001

in the open air for twenty hours from 100 mm. diameter crystallizing dishes containing 10 cc. of liquid. Results noted in Table III, show that the end members are stable, and that 300°F flashpoint kerosene is a higher grade raw material than crude kerosene. The changes in index of the mixtures of the end members are ascribed to differential evaporation, but even these are not as serious as appears. Divided by twenty, the index change in one hour would be about 0.0002 if the surface is freely exposed, but in working with a covered slide, the amount of liquid surface is so slight that it is doubtful if any index change could be detected even if the slide were several hours old. However, elevated temperatures will decrease the time limit.

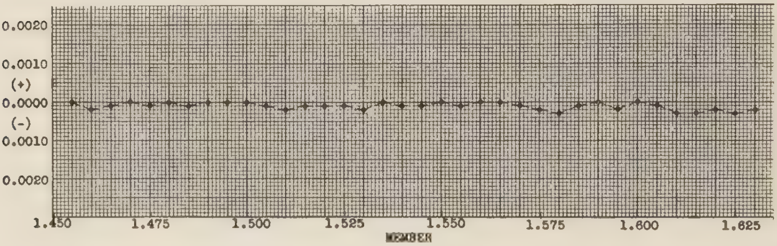


FIG. 8. Stability of the members of the series determined after 12 months use. The horizontal line represents the standardized indices and the encircled points show the deviation. The greatest is 0.0003 and the average is 0.0001.

The members of the series have been kept in the standard double-stoppered bottles, and the maximum index change after one year of laboratory use was 0.0003, the average being 0.0001. Fig. 8 shows these changes plotted against the members. Several index determinations were made after eighteen months, and as no further changes were indicated, the liquids fulfill the desired feature of constancy.

It should be noted that the liquids are constant with respect to both storage and use, and hence recommend themselves not only to ordinary comparative immersion methods, but also to possible application with the variation technique.

DUPLICATION

This series of immersion liquids can be duplicated exactly. This confers an advantage to those who do not have the time to analyze optical properties in detail, as duplication of the series means duplication of the properties.

The duplication of the indices of the end members present the only difficulties, but this may be remedied by adjusting to the writer's mixing curve (Fig. 1), or by determining a new mixing curve.

Through close tabulation of distillate fractions, the index of the lower end member may be brought to the value, $n_D = 1.4500$, and will therefore correspond to a point on the present curve.

Should the index of the α-monochlornaphthalene available be too high, $n_D > 1.6324$, a secondary standard of correct index may be formed by adding some of the lower end member, sufficient to bring it to this index, and this may be regarded as the equivalent of a primary standard.

Should the index of the α-monochlornaphthalene, however, be too low, $n_D < 1.6324$, it cannot be raised without addition of material extraneous to the series. This difficulty may be overcome by a new mixing curve whose form is based on that in Fig. 1, but whose termination at 0.00 cc. kerosene fraction and 16.00 cc. α-monochlornaphthalene is placed at the actual index value of the upper end member. To accomplish this, proceed as follows: On an exact duplicate of Fig. 1, locate the kerosene fraction index at 16.00 cc. kerosene and the α-monochlornaphthalene index at 16.00 cc. α-monochlornaphthalene. Connect these two points by a trial straight line. At a composition corresponding to 50% of each end member, locate an index 0.0010 higher than that indicated by the trial straight line. (Alternatively, this correction may be determined by measuring the index of a 50% mixture and subtracting the calculated value based on the straight line theory of liquid mixtures.) Now draw a smooth flat curve through the kerosene index point, the 50% corrected index point, and the α-monochlornaphthalene index point. The resulting mixing curve will yield a system of liquids whose properties will be identical to those described.

The writer is indebted to Professor M. J. Buerger for proposing this investigation, as well as for invaluable criticisms and suggestions during its progress.

ADDITIONAL NOTES ON LAUMONTITE AND THOMSONITE FROM TABLE MOUNTAIN, COLORADO

E. P. Henderson, *U. S. National Museum and*
Jewell J. Glass, *U. S. Geological Survey.*[1]

Introduction

Table Mountain, a conspicuous geological feature near Golden, Colorado, has long been known as a locality for zeolites. Cross and Hillebrand,[2] Patton,[3] Clarke and Steiger[4] have described these minerals in detail and since then several other articles have appeared on the zeolites from this locality, but the various authors have added no new analyses of laumontite. Hey[5] recently published two analyses of thomsonite but aside from these no recent analyses of the Table Mountain thomsonite have been reported.

On a recent visit (by E. P. H.) to the quarry located on the western rim and well to the southern end of North Table Mountain, considerable quarrying was done in the hope of exposing some suitable mineral specimens. A number of different zeolites were exposed and among them a golden-brown sandy laumontite which almost completely fills some of the vesicular cavities in the basalt. All the zeolites obtained by the author's quarrying activities were inferior mineral specimens, but the Colorado School of Mines which operated this quarry several years ago kindly donated to the U. S. National Museum a suite of good specimens of the different zeolites from this locality.

Laumontite

The specimen studied came from the Colorado School of Mines and had been exposed to the air in their collections for several years without any special precautions to prevent dehydration. Because of its apparent freshness and unusual golden-brown color this material seemed worthy of an investigation to determine if it were a normal laumontite. A very narrow reddish-brown reaction ring confined within the altered basalt follows the contact of the vesicular cavity, largely filled with the zeolites, and shows that the solutions introducing the zeolites have had some effect upon the basalt.

---

[1] Published with permission of the Secretary of the Smithsonian Institution and the Director, of the U. S. Geological Survey.

[2] *Amer. Jour. Sci.*, **23**, p. 452, 1882; **24**, p. 129, 1882; and *U. S. Geol. Surv., Bull*, **20**, p. 13, 1885.

[3] *Geol. Soc. Amer. Bull.*, **11**, p. 461, 1900.

[4] *U. S. Geol. Surv., Bull.* **207**, p. 34, 1902.

[5] *Mineral. Magazine*, **33**, p. 54, 1932.

A sharply defined veinlet of brown thomsonite, about one quarter of an inch wide, separates a band of light brown compact laumontite of about equal thickness from the loosely bonded golden-brown laumontite in the center of the cavity. This thomsonite veinlet is discontinuous in several places and the compact laumontite fills the gap and grades gradually out into the golden-brown laumontite in the center. Little or no alteration has taken place within this thomsonite veinlet. There are, however, small segregations of brown iron oxide confined to the thomsonite along its contact with the golden-brown laumontite.

The golden-brown laumontite which fills the central portion of this cavity is quite uniform in texture and almost free from other zeolites. A few isolated spherulites of thomsonite are present, mostly limited to regions close to the thomsonite veinlet. As you proceed farther into the laumontite and away from the thomsonite veinlet, the more altered the spherulites become. The alteration product of the thomsonite is a soft white powder which in most cases preserves the original form of the spherulite. During the alteration there has been a decrease in volume as many of these white powdery spherulites are now hollow shells. Minor cracks in the golden-brown laumontite have been filled with a later generation of colorless laumontite.

The laumontite has a very uniform golden-brown color and bright luster, without the slightest suggestion of any alteration or apparent dehydration, thus differing from most laumontites. The texture is granular, the individual grains being slightly elongated with a few rather poorly developed faces in the prismatic zone. No terminal faces were seen.

The following optical determinations[6] were made on the same sample of the golden-brown laumontite whose analysis is given in Column 1 of Table II.

$\alpha = 1.504$, $\beta = 1.514$, $\gamma = 1.516$, Optically $(-)$, $2V = 25°–35°$, dispersion $\rho < v$. Extinction highly inclined, $c \wedge Z = 30°–36°$

The indices of this laumontite are considerably lower than those given by Larsen[7] but are consistent with the values reported by him[8] for the material from Wolf Creek Station, Montana, analyzed by Shannon, and for that described by McClellan[9] from the Cascade Mountains, Oregon, also analyzed by Shannon.

---

[6] Optical determinations made by J. J. Glass.

[7] *U. S. Geol. Surv., Bull.* **679,** p. 245, 1921.

TABLE I. COMPARISON OF OPTICAL INDICES OF LAUMONTITE

	1	2	3	4
α	1.504	1.513	1.505	1.505
β	1.514	1.525	1.515	—
γ	1.516	1.524	1.517	1.513
$\gamma-\alpha$	0.012	0.011	0.012	0.008

(1) Table Mt., Colo.
(2) Locality not reported. *Op. cit.*
(3) Wolf Creek Station, Mont. *Op. cit.*
(4) Cascade Mountains, Oreg. *Op. cit.*

The birefringence of numbers 1, 2, 3, are all consistent even though the indices of no. 2 are considerably higher than the others.

TABLE II. ANALYSES AND RATIOS OF LAUMONTITES FROM TABLE MT., COLORADO

	1	2	3
	Golden-brown	Yellow Crystals	White crystals
SiO_2	50.82	51.43	52.07
Al_2O_3	20.06	21.52	21.30
Fe_2O_3	2.18	0.94	—
CaO	12.14	11.88	11.24
MgO	0.02	—	—
K_2O	0.22	0.35	0.42
Na_2O	0.31	0.19	0.48
H_2O	14.87	13.81	14.58
V	None	N.D.	N.D.
Total	99.97	100.12	100.09
RO	1.00	1.00	1.00
R_2O_3	1.01	0.96	0.98
SiO_2	3.76	3.90	4.11
H_2O	3.68	3.50	3.81

(1) E. P. Henderson, analyst.
(2, 3) W. F. Hillebrand, analyst.

The uniform bright golden-brown color and the freedom from any alteration indicates that the 2.18 percent ferric iron is present isomorphously with the alumina. Qualitative tests showed no vanadium present. The molecular ratio between $R_2O_3(Al_2O_3+Fe_2O_3)$ and RO $(CaO+K_2O+Na_2O)$ is 1.01:1.00. Winchell[10] selected a series of analyses of laumontite in which the ratio between Al_2O_3 and $CaO+Na_2O$ was 1:1, and if these same analyses are averaged for their molecular ratios the following proportions are obtained:

---

[8] *Amer. Min.*, **6**, p. 6, 1921.

[9] *Amer. Min.*, **11**, p. 287, 1926.

$$RO:R_2O_3:SiO_2:H_2O=1.00:1.01:4.05:3.65.$$

When the molecular ratios of this golden brown laumontite are compared with the averages given, there is close agreement, except for the SiO_2. The silica ratio of this golden-brown laumontite is 7.16% lower than the averaged ratios.

THOMSONITE

The best of the closely packed small brown spherulites of thomsonite, associated with the brown laumontite, were selected for analysis with the object of confirming the identity of the mineral rather than of describing an unusual variety of thomsonite.

TABLE III. ANALYSES AND MOLECULAR RATIOS OF THOMSONITE FROM TABLE MT., COLORADO

	1	2	3
SiO_2	38.55	40.3	40.73
Al_2O_3	29.08	28.5	29.93
Fe_2O_3	1.89	—	—
CaO	12.14	11.2	12.17
Na_2O	4.38	5.7	4.66
K_2O	0.44	—	—
H_2O	14.02	14.1	12.55
MgO	0.04	—	—
	100.77	99.8	100.04
RO	1.00	1.00	1.00
R_2O_3	1.01	0.97	1.00
SiO_2	2.19	2.32	2.31
H_2O	2.66	2.70	2.38

(1) E. P. Henderson, analyst.
(2, 3) M. H. Hey, analyst, *Op. cit.*

---

[10] *Amer. Min.*, **10**, p. 112, 1925.

The material selected, by hand picking, for the analysis was not entirely free from impurities as it was impossible to remove all of the adhering laumontite and brown iron oxide. However, the percentages of these impurities in the sample analyzed are very small.

The optical properties[11] determined upon the analyzed material, Column 1, Table III, are as follows: $\alpha=1.518$, $\beta=1.521$, $\gamma=1.531$. Optically +, $2V=54°$ (measured), dispersion $\rho>v$. Orientation, $a=X, b=Z, c=Y$.

A small portion of the thomsonite showed a larger axial angle, $2V=72°$ (measured). Also a portion, obtained from the hand picked sample, had somewhat lower indices of refraction, namely $\alpha=1.513$, $\beta=1.519$, $\gamma=1.527$. No intermediate values were obtained.

The purpose of this paper is to place on record two new analyses and accompanying optical data. No additional relationships between the different zeolites at this locality were noted.

---

[11] Determined by J. J. Glass.

NOTES AND NEWS

NOMINATIONS FOR OFFICERS OF THE MINERALOGICAL SOCIETY OF AMERICA FOR 1934

The Council has nominated the following for officers of the Mineralogical Society of America for the year 1934:

President: John E. Wolff, Pasadena, California.

Vice-President: W. A. Tarr, University of Missouri, Columbia, Missouri.

Treasurer: Waldemar T. Schaller, U. S. Geological Survey, Washington, D. C.

Secretary:*

Editor: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

Councilor (1934–1937): Edward P. Henderson, U. S. National Museum, Washington, D. C.

The fourteenth annual meeting of the Society will be held December 27–29, 1933, at the University of Chicago, Chicago, Illinois. It is planned to publish in the December issue of the Journal a *preliminary* list of titles of papers to be presented before the Society at its annual meeting. In order to appear on the advance program, titles of papers should be in the hands of the Secretary *pro tem.* by *November 10.*

Albert B. Peck (Ann Arbor, Mich.), *Secretary, pro tem.*

* Due to the sudden death of Dr. Van Horn on Aug. 1, 1933, the Council has not had an opportunity, at the time this issue goes to press, to recommend his successor. The Council's recommendation for this and other offices of the Society will be printed on the official ballot and mailed to all fellows and members about Nov. 1, 1933.

The State Bureau of Mines has recently issued Bulletin **7,** The Metal Resources of New Mexico and their Economic Features, by S. G. Lasky and T. P. Wootton. The bulletin contains 178 pages and is illustrated by tables and maps showing the location of the various districts.

The total metal production of New Mexico from the advent of the Spaniards to 1930 is stated by the authors to have a value of 419 million dollars. About 80 per cent of this amount is accounted for by mining operations from 1904 to 1930. Since the beginning of mining the value of the various metals produced has been as follows: Copper $247,637,000, silver $51,645,000, gold $45,997,000, zinc $44,010,000, lead $18,140,000, iron ore $7,919,000, managanese and manganiferous ores $2,293,000, molybdenum, $1,789,000, and tungsten ore $125,000.

In Bulletin 7 all available information of value to those interested in mining in New Mexico has been assembled. All of the known mining districts are described briefly with attention to history, production and geology. The uses of the metals and the marketing of the different ores are described. The section on the economic features of prospecting, mining and milling contains important data on costs of construction and operation and should be of special value to those who are giving thought to acquiring or developing mining properties.

At a meeting of representative retail jewelers held in Chicago a permanent organization known as the Gemological Institute of America was established. One of the main objects of this Society is to furnish adequate scientific instruction to those responsible for the sale of gems and gem materials. A constitution was adopted, plans formulated for the future and officers elected to the various boards and committees. Mr. Robert M. Shipley of Los Angeles, California, was elected president of the Institute.

Dr. Hermann Michel was elected Director of the Natural History Museum at Vienna. He will retain however the supervision of the work in mineralogy and petrography.

Dr. Bruno von Freyberg has accepted the professorship of geology and mineralogy at the University of Erlangen as successor of Dr. Hans Lenk.

Dr. Frank R. Van Horn, Secretary of the Mineralogical Society of America, and Professor of geology and mineralogy at Case School of Applied Science, Cleveland, Ohio, died Aug. 1, 1933, at the age of sixty-one years.

DIRECTORY OF AMERICAN AND CANADIAN MINERAL COLLECTIONS

Samuel G. Gordon, *Academy of Natural Sciences of Philadelphia.*

(Continued from page 366).

MINNESOTA

Collegeville St. John's University.

Jackson Joseph N. Prokes.

A general and local collection of 2000 specimens.

Lake Crystal Frank O. Swain.

Minneapolis Minnesota Academy of Science.

Museum in Public Library Building.

University of Minnesota.

Department of Geology and Mineralogy. A general series, including the first collection of George Frederick Kunz, of 2000 specimens, is in Pillsbury Hall. It may be seen during school hours.

Northfield Carleton College.
St. Olaf College.
Soudan Oscar J. Corpi, P.O. Box 775.

St. Paul Hamline University, Geological Museum.

A small general collection of minerals.

St. Paul Institute of Arts and Sciences.

St. Peter Gustavus Adolphus College.

A general collection of 500 minerals may be seen in the Main Hall on application.

Winona Winona State Teachers College.

MISSISSIPPI

Jackson Millsaps College.

Mr. J. M. Sullivan is custodian of a collection of about 1000 specimens.

State College State College (Formerly Mississippi Agricultural and Mechanical College).

A collection of about 1000 specimens may be seen daily from 9 a.m. to 5 p.m. in the Department of Geology.

University University of Mississippi.

Teaching collections, and the collections of the State Geological Survey are in care of the Department of Geology.

MISSOURI

Canton Culver-Stockton College.

Columbia University of Missouri, Museum.

Fayette Central College.

Fulton Westminister College.

GLASGOW PRITCHETT COLLEGE.

JEFFERSON CITY MISSOURI STATE MUSEUM (Resources Museum Commission).

Alfred C. Burrill, Curator. In 1923 the St. Joseph Lead Co. presented part of the remarkable collection brought together by F. P. Graves while Superintendent of the Doe Run Lead Co. It was originally displayed in the offices of the latter company at Doe Run, previous to its acquisition by the St. Joseph Lead Company. Although the collection is a general one, it contains huge calcite crystals, and other noteworthy Missouri minerals.

KANSAS CITY DANIEL B. DYER MUSEUM, Public Library Building.

ROLLA BUREAU OF GEOLOGY AND MINES.

State Geologist (H. H. Buehler), Custodian. The State collections, numbering 5000 specimens, may be seen daily, except Sunday, from 8 A.M. to 5 P.M., on request.

MISSOURI SCHOOL OF MINES AND METALLURGY, GEOLOGICAL MUSEUM.

Contains the Col. Kingston collection, rich in pseudomorphs.

SPRINGFIELD DRURY COLLEGE, Edward M. Shepard Museum.

Contains the collection of Sanborn Tenny.

ST. LOUIS EDUCATIONAL MUSEUM OF THE ST. LOUIS PUBLIC SCHOOLS.

FREDERICK H. POUGH, 4 Lenox Place.

A general collection of 1800 specimens.

WASHINGTON UNIVERSITY.

Mr. W. O. Shipton is custodian of a general teaching collection in Wilson Hall, numbering 16,000 specimens. It may be seen at any time.

MONTANA

AGATE COOLS MUSEUM OF NATURAL HISTORY.

BOZEMAN UNIVERSITY OF MONTANA (Montana State College), Department of Chemistry.

A rather small mineral collection.

BUTTE MONTANA SCHOOL OF MINES.

Custodian, Eugene S. Perry. The general collections include over 30,000 minerals, rocks, and fossils. They may be seen weekdays from 8 A.M. to 5.30 P.M., and on Saturdays from 8 A.M. to 12 M.

Helena Montana State Library, Museum.

State Capitol Building.

Missoula University of Montana.

NEBRASKA

Crete Doane College.

A general collection of minerals. C. O. Carlson, Custodian. May be seen on request.

Hastings Hastings College.

A general collection of 1000 specimens is in custody of W. J. Kent, and may be seen in the main building daily and on Sunday afternoons.

Lincoln University of Nebraska: State Museum.

Erwin H. Barbour (Department of Geology), Director. The museum and the mineral collection are both in process of building. While emphasizing Nebraska resources, ouly a few common minerals are exhibited. The completed portion of the museum is open daily from 8 A.M. to 6 P.M. and on Sundays from 2 P.M. to 6 P.M.

Omaha Creighton University, Museum.
Fred Eastman, 2628 Dodge Street.

A general collection of 450 specimens.

Omaha Public Library and Museum.
University Place Nebraska Wesleyan University.

NEVADA

Coaldale Carl Rieck.

Lovelock Captain A. H. Scott.

Collection of ores.

Lower Rochester Percy Train.

A large collection of minerals and fossils.

Manhattan H. G. Clinton.

A collection of 5000 specimens, including many local minerals.

Reno Mackay School of Mines, Mackay Museum.

About 32,700 minerals, ores, rocks, and fossils comprise the collections in custody of Mr. Carl Stoddard. Included is the collection, formerly in the State Capitol at Carson City, and the Cole, Malcolm McDonald, C. W. West, and F. M. Fellows collections. The Museum is open daily except Sunday.

TONOPAH C. C. BOAK.

A general collection of 1400 specimens.

TUSCARORA RAY LA FORCE.

A collection of Rocky Mountain ores.

NEW HAMPSHIRE

DURHAM NEW HAMPSHIRE COLLEGE OF AGRICULTURE AND MECHANIC ARTS.

(State Geological Survey Collections.)

UNIVERSITY OF NEW HAMPSHIRE, Conant Building.

George W. White, Custodian. A general and local collection of New Hampshire minerals and rocks.

HANOVER DARTMOUTH COLLEGE, BUTTERFIELD MUSEUM.

Frederick Hall Collection.

KEENE WALTER E. HAMMOND, 573 West Street.
KEENE HIGH SCHOOL.
KEENE NATURAL HISTORY SOCIETY.

This society, founded in 1833, has a collection numbering 5000 minerals and 2000 rocks in the Library building, where it may be seen daily, or by appointment with the Custodian, Mr. Hayward. It includes New England and New Jersey minerals.

MANCHESTER GEORGE I. HOPKINS.
MANCHESTER INSTITUTE OF ARTS AND SCIENCES.

George I. Hopkins, Custodian. A general collection of 5000 specimens. Open daily 10 A.M. to 4 P.M. The Institute lost its more extensive mineral collection in a fire in 1902.

WOLFEBORO LIBBY MUSEUM.

NEW JERSEY

ASBURY PARK FRED C. METCALFE, P.O. Box 51.

A small collection.

BLOOMFIELD ROY M. ALLEN, 126 Berkeley Avenue.

CALDWELL ERNEST H. WILSON, 37 Forest Avenue.

A general and local collection of 2000 specimens, particularly of New Jersey zeolites.

Dover Tom Allen, Hewey Avenue.
C. M. Berry, 21 East McFarland Street.
High School.

Elizabeth P. Walther, 508 Muriel Parkway.

A general and local collection of 3000 specimens.

Franklin William Ball.

Local collection.

L. H. Bauer.

Fine local collection.

Sidney Hall.

Local collection.

W. J. Garrity.

Local collections.

James McGovern Collection.

Owned by Quinn. Local collection.

New Jersey Zinc Company.

A local collection is in the office.

Captain Rowe.

A large local collection.

Hoboken Stevens Institute of Technology, Museum.

Hopewell J. P. Labaw.

A general collection.

Jersey City Jersey City Public Library, Museum.
O. Ivan Lee, 2684 Boulevard.

Menlo Park Collection of Thomas Alva Edison.

Newark William H. Broadwell, 571 Hawthorne Avenue.

Collection includes New Jersey minerals, particularly from Franklin, minerals of the rarer elements, and box mounts for the microscope.

Newark Museum Association, 49 Washington Street.

Beatrice Winser, Director. The collection of 5200 specimens of the late William S. Disbrow, particularly rich in New Jersey zeolites, and the private collection of about 5000 gems and gem materials of Mr. Otto Goetzke are exhibited in the Museum.

NEW BRUNSWICK JOHN A. MANLEY, 132 Hamilton Street.

A general and local collection of 2500 specimens.

RUTGERS COLLEGE, Geological Museum.

Contains the collections of George H. Cook, Lewis C. Beck, (kept intact), and of Albert H. Chester. Rich in New York and New Jersey minerals.

NUTLEY WILLIAM T. BATHER, 180 Prospect Street.

ORANGE LOUIS REAMER, 484 Lincoln Avenue.

A general and local collection, including a series of box mounts for the microscope.

PATERSON PATERSON MUSEUM, 268 Summer Street.

James F. Morton, Curator. A general and local collection, particularly of Paterson and Franklin minerals is on exhibition. The collection contains about 580 species.

PRINCETON UNIVERSITY, Guyot Hall.

Contains the collections of Samuel Fowler (in part) and of Archibald MacMartin.

RUTHERFORD WILLIAM J. IHNEN, 133 Mortimer Avenue.

TABOR ALVIN HILL, Box 4. (12 Trinity Circle).

A general and local (Franklin) collection of 1500 specimens.

TRENTON MRS. WEBSTER EDGERLY: 349 W. State Street.

R. B. GAGE, Box 106.

A collection of 1500 specimens, principally from Franklin, N. J.

STATE MUSEUM OF NEW JERSEY, State House Annex.

The Museum, which is associated with the State Geological Survey, has a small mineral collection. It may be seen from 9 A.M. to 5 P.M. daily, and on Sunday afternoons.

VERONA R. SCHMID.

WEST CALDWELL JULIA POTWIN MEMORIAL LIBRARY.

A small collection of minerals.

NEW MEXICO

ALBUQUERQUE UNIVERSITY OF NEW MEXICO, Museum.

MESILLA PARK NEW MEXICO COLLEGE OF AGRICULTURE AND MECHANIC ARTS

SANTE FE NEW MEXICO HISTORICAL SOCIETY.

SOCORRO NEW MEXICO SCHOOL OF MINES, Department of Geology.

A small collection of 1200 minerals may be seen in Brown Hall on request to the custodian, Prof. S. B. Talmadge.

NEW YORK

ALBANY NEW YORK STATE MUSEUM, (State Education Building).

C. C. Adams, Director. About 15,000 specimens comprise the general and New York State collections, which include the cabinets of Ebenezer Emmons, Silas C. Young, the fourth collection of George Frederick Kunz, and some minerals from the collection of Lewis C. Beck. The Museum is open daily from 9 A.M. to 5 P.M., and on Sundays from 2 to 5 P.M. from October 1st to May 1st.

ALFRED ALFRED UNIVERSITY.

ANNADALE, Staten Island. THOMAS I. MILLER.

A general collection of 700 specimens, including a series of box mounts of minerals for the microscope.

AURORA WELLS COLLEGE.

BINGHAMTON BINGHAMTON ACADEMY OF SCIENCE.

BROOKLYN GEORGE E. ASHBY, 265 Washington Avenue.

A general collection of 3500 specimens, including a series of New York City minerals, and a collection of pseudomorphs. Specializes in hydrocarbons.

BEULAH AND MAURICE BLUMENTHAL, 558 Irving Street.

A large collection, principally of carved semi-precious stones.

BROOKLYN MUSEUM, Eastern Parkway. CHILDRENS MUSEUM, Brooklyn Avenue.

The Brooklyn Museum contains the Daniel S. Martin Collection, in part.

JOHN A. GRENZIG, 299 Adams Street.

A general and local collection.

ERWIN F. GROSS, 1169 E. 37th Street.

A small collection.

CHARLES W. HOADLEY, 145 Willow Street.

A collection of 5000 specimens.

Long Island Historical Society

Polytechnic Institute of Brooklyn.

Said to have the John Milton Smith collection.

Buffalo **Buffalo Museum of Science, Humboldt Park.**

The mineral collection, including the Wadsworth cabinet, numbers 10,000 specimens.

Canisius College.

State Normal School.

University of Buffalo.

Canton **St. Lawrence University.**

Genesee **Genesee Valley Museum.**

Clinton **Hamilton College.**

Over 20,000 minerals, ores, rocks, and fossils are in the collections in the Biology-Geology building, which include the cabinets of Oren Root and John D. Conley. Nelson C. Dale is Custodian. The collection may be seen daily.

Cortland **Free Library.**

About 200 minerals are in the museum and part of basement, and may be seen during library hours: 9 A.M. to 9 P.M.

Geneva **Hobart College.**

Greystone **William Boyce Thompson Collection.**

Dr. Fred J. Pope (New Rochelle), Curator. A large collection of showy minerals and carved jades, extraordinarily well displayed.

Hamilton **Colgate University, Geological Museum.**

Exhibits include the collections of J. H. Ten-Eych Burr (rarer pegmatite minerals), John H. H. Vosburgh (Little Falls, and Middleville quartz crystals), and the Edward Lathrop Memorial Collection of William Urban—a general collection of 1200 specimens (including some cut stones), and particularly rich in zeolites.

Ithaca **Cornell University.**

Reported to have the collection of Benjamin Sillman, Jr.

Jamaica **Ernest A. Maynard, 161-86th Avenue.**

A general collection of 1200 showy minerals.

Menands **Harry S. Peck.**

New Rochelle Glen Island Museum of Natural History.

New York (See also under Brooklyn and Staten Island).
Academy of Mt. St. Vincent.

Said to have the collections of E. S. F. Arnold, and Benjamin F. Joslin.

Frederick I. Allen, 55 East 65th Street.

American Museum of Natural History.

H. P. Whitlock, Curator of Mineralogy. Contains the famous collection of Clarence Bement, who had acquired the collection of Norman Spang. Incorporated in these collections are the cabinets of Joseph F. Talson, and S. C. H. Bailey (his meteorite collection is exhibited in another hall of the museum). The Benjamin B. Chamberlain Collection of Manhattan minerals, and other local minerals brought together by the New York Mineralogical Club are appended to the general collection. Prominence is given to the J. P. Morgan Gem Collection, one of the outstanding gem collections in America, formed from the Tiffany gem exhibits at the Paris expositions of 1889 and 1900. The William Boyce Thompson Collection is destined for the American Museum of Natural History. The late Dr. Drummond bequeathed his collection of old carved jades to the Museum.

College of the City of New York, Convent Avenue and 139th Street.

The collection of 5000 specimens includes a fine series of New York rocks and minerals. It may be seen in the main building daily except Sunday.

Columbia University, School of Mines: Schermerhorn Hall (Egleston Mineralogical Museum).

The rather extensive collection of Thomas Egleston is on exhibition. Incorporated with it is the Henry Howe collection of Nova Scotia Zeolites.

Morris Cooper, 1155 Park Avenue.

Cooper Union.

Dr. I. W. Drummond, 436 West 22nd Street.

Fordham University.

Albert F. Karlsson, 265 East 201st Street.

Manhattan College.

Metropolitan Museum of Art.

Contains the famous Bishop Collection of Carved Jades.

Montgomery Arthur, 111 East 56th Street.

New York University.

Contains the Joseph Delafield Collection.

Robert R. Oppenheimer, 155 Riverside Drive.

John W. Radu, Stuyvesant High School, 345 East 15th Street.

Society of Ethical Culture.

Said to have the Lewis Feuchtwanger Collection.

Var-Lac-Oid Chemical Company, 15 Moore Street.

A few mineral specimens.

Niagara Falls — Niagara University.

Pelham Manor — Ernest Weidhaas, 63 Iden Street.

Peekskill — Peter Zodac, 157 Wells Street.

Poughkeepsie — Vassar College.

A general collection of 2000 specimens may be seen from 8 to 5 daily during the college year in the New England Building.

Rochester

George L. English, 50 Brighton Street.

A collection of box mounts of minerals for the microscope.

Rochester Museum of Arts and Sciences.

A general and local collection of 2000 specimens. Arthur C. Parker, Custodian. Open from 9 A.M. to 5 P.M., except Sundays.

A. L. Stevens, 691 Culver Road.

A general collection of 2200 specimens.

University of Rochester, Museum of Natural History.

A general collection of 15,000 specimens may be seen on request, in Dewey Building. E. J. Foyles is Custodian.

Schenectady — Union College.

The collections, which number 10,000 specimens, include the cabinet of Charles M. Wheatley—rich in Phoenixville, Pa., and Bristol, Conn., minerals, and the Thomas B. Brooks collection, in part. They may be seen in the Geology building upon application to Prof. E. S. C. Smith.

Schoharie — Schoharie County Historical Society.
R. Veenfliet.

A large collection, principally of fossils.

Shrub Oak — James H. C. Martens.

Collection is in charge of Mrs. Genevieve Martens.

Silver Bay — Silas H. Paine Private Museum.

Skaneateles — Library Association.

St. George — Staten Island Institute of Arts and Sciences.
Wall Street and Stuyvesant Place.

General and local (Staten Island) collections, including the cabinets of F. Hollick and Sanderson Smith. Museum is open 10 to 5 week days, 2 to 5 Sundays.

Syracuse — Syracuse University.

The Museum of Natural History contains the Charles H. Richardson Collection, the W. A. Brownell Collection, and the D. B. Cooper collection—largely from Yellowstone Park.

Troy — Rensselaer Polytechnic Institute.

About 6500 minerals are in the collection in the Pittsburgh Building. Dr. Joseph L. Rosenholtz is Custodian. The collection may be seen on Tuesdays and Thursdays from 4 to 5 p.m.

Utica — George W. Coram, 912 John Street.

A general collection.

Edmund Everett Hobbs, Sr., 513 Nichols Street.

A small mineral collection.

West Point — U. S. Military Academy.

Yonkers — Yonkers Museum of Science and Arts, Trevor Park.

About 1500 specimens are exhibited in 6 cases. Open daily, from 9 a.m. to 12 m., and 2 p.m. to 5 p.m., and on Sundays and Holidays from 2 p.m. to 5 p.m. The collection is destined for the American Museum of Natural History.

(*To be continued*)

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

The Academy of Natural Sciences of Philadelphia, May 4, 1933

A stated meeting of the society was held with President Trudell in the chair and 44 members and 32 visitors present. The following names were proposed: for full membership, Nicola C. D'Ascenzo, Jr.; for junior membership, David Walker and William Hutchinson.

Dr. Alfred K. Snelgrove of Princeton University spoke on "Geological and Mineralogical Explorations in Newfoundland," which was illustrated with charts, maps, and lantern slides. The island has an area of 42,000 square miles, and is an extension of the Appalachian mountain province. It has been glaciated during the Jersey and Wisconsin periods, excepting a small area in the western part. The Wabana iron ore deposits of Bell Island consist of oolitic hematite, with chamoisite and siderite. The three beds, of sedimentary origin as shown by the fossils they contain, vary from 10 to 25 feet in thickness, with workings extending two miles under the sea. Other ore deposits described were the Ordovician copper deposits of Notre Dame Bay, the deposit of lead, zinc, and copper at Tilt Cove; the pyrite deposit at Betz Cove, and the chromite deposit in serpentine at Bay of Islands. Mr. R. G. Stafford then showed motion pictures taken on a trip across Newfoundland.

Trips to Franklin, and Paterson, New Jersey, were described by Messrs. Toothaker, Oldach, Gordon, and Cienkowski. Mr. Toothaker exhibited triboluminescent willemite from Franklin and Mr. Varni displayed specimens of boulder opal from Queenland. Mr. Petersen reported finding moonstone, and amazonstone at Mineral Hill in Delaware County.

W. H. Flack, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

Mineralogical Society, 15th June, 1933, Sir John S. Flett, President, in the chair.

Dr. L. J. Spencer: *Minute spheres of nickel-iron in the silica-glass from the meteorite craters at Wabar, Arabia.* Micro-sections of the silica-glass show, in addition to many vesicles, vast numbers of minute black spots. From the crushed material these can be picked out with a magnetic needle in long strings and clusters. They are perfect spheres with a highly polished surface and consist of metallic iron with 8.8% of nickel. In size they range from 0.14 to 0.003 mm. in diameter, and an estimate of their number gives two million per cubic centimeter.

Prof. G. E. Tilley: *Portlandite, a new mineral from Scawt Hill, Co. Antrim.* A brucite-like mineral occurring in isolated patches in a spurrite-larnite assemblage in the chalk-dolerite contact of Scawt Hill. This proves on analysis to be $Ca(OH)_2$. This is new as a mineral, and the name Portlandite is proposed for it. Optical properties agree with the artificially prepared material studied in connection with Portland Cement.

Mr. S. I. Tomkeieff: *Clay minerals and bauxite minerals.* A review and classification based on a statistical method. Clay minerals and bauxitic minerals which occur usually in a state of fine-grained aggregates are difficult to classify. The majority of the existing analyses apparently refer to mixtures of minerals and not to pure compounds. The present paper represents an attempt to classify the existing chemical data by plotting on triangular diagrams. The number of analyses used is as follows: For the system $H_2O-Al_2O_3-SiO_2$, 689, and 320 for the system $H_2O-Al_2O_3-Fe_2O_3$. This method indicates the definite existence of the following crystalline minerals, pyrophyllite, $H_2O\cdot Al_2O_3 4SiO_2$, kaolinite and its polymers, $2H_2O\cdot Al_2O_3\cdot 2SiO_2$, diaspore and boehmite, $H_2O\cdot Al_2O_3$, gibbsite, $3H_2O\cdot Al_2O_3$, goethite, $H_2O\cdot Fe_2O_3$. Newtonite and bauxite ($2H_2O\cdot Al_2O_3$) prove to be non-existing as minerals. A group of minerals including beidellite and montmorillonite, containing a certain amount of basic oxides are separated from the pure clay minerals under the name of bentonite group. The genetic relation between the various mineral groups studied and certain rock-forming minerals such as the micas and the feldspars is briefly outlined.

Mr. M. H. Hey: *Studies on the Zeolites*. Part VI. Edingtonite (with *x*-ray measurements by Mr. F. A. Bannister.) A chemical, optical, and *x*-ray examination has been made of edingtonite from Böhlet, Sweden. The unit-cell formula is $Ba_2Al_4Si_6O_{20},\cdot 8H_2O$, and the mineral is not isostructural with thomsonite or with the mesotype group, a result which is confirmed by base-exchange experiments. The vapor-pressure surface of edingtonite has been studied by the methods used for other zeolites; there is no evidence of any other distinct hydrate or modification.

Mr. M. H. Hey: *On the accuracy of mineralogical measurements*. A review of the probable accuracies to be expected in measurements of a variety of physical constants of minerals by the usual methods. It is shown that published results are often calculated to far more places of decimals than the measurements can possibly warrant.

Dr. S. R. Nockolds and Mr. E. G. Zies: *On a new barium plagioclase feldspar*. A barium 'anemousite' feldspar has been found to occur in certain aplitic dikes in the Broken Hill district, New South Wales. This feldspar shows several kinds of plagioclase twinning with (−)2V varying from 74°–82° and an average value of 78°. Indices of refraction: $\alpha=1.571$, $\beta=1.580$, $\gamma=1.585$, $\gamma-\alpha=.014$. Dispersion weak. The position of the optic plane and the optic axes corresponds quite closely with the position of these elements for plagioclases towards the basic end of the series. The feldspar has been analyzed and corresponds in composition to $Or_4Ne_4Ab_9$-$Ce_{14}An_{69}$. Sp. gr. 2. 872 at 17°C.